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ARTS

DEVSEKH AS A FOUNDATIONAL MOVEMENT OF MONGOLIAN DANCE: RITUAL STAMPING, BODILY TECHNIQUE, AND THE LIVING REPERTOIRE

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Abstract

This article examines the Mongolian traditional dance movement *devsekh* through its physical actions, spatial organization, and embodied rhythmic force as documented in historical and ritual sources. Focusing on recurrent actions—such as forceful stamping or pressing of the ground, circular motion, and forward-driven steps—the study analyzes how *devsekh* produces meaning through bodily contact with the earth, repetition, and collective synchronization. Descriptions from *The Secret History of the Mongols* and Rashid al-Din's *Compendium of Chronicles*, together with references to "song dance with stamping feet" in Yuan dynasty poetry, reveal the movement's continuity across ritual, pastoral life, military ceremony, and court culture. These sources demonstrate that *devsekh* is structured by downward force, rhythmic grounding, and spatial marking, leaving material traces on the ground and reproducible patterns within corporeal memory. Rather than approaching *devsekh* primarily as symbolic representation, the article positions it as a foundational movement practice through which Mongolian dance generates meaning via bodily exertion, rhythm, and spatial occupation.

Keywords: devsekh; Mongolian dance; bodily technique; rhythmic force; living repertoire

Introduction

In Mongolian circle dance traditions, ***devsekh*** has been preserved across generations as a foundational movement characterized by repetitive rhythm and vigorous engagement between body and environment. Historical sources such as *The Secret History of the Mongols*, Rashid al-Din's *Compendium of Chronicles*, and literary works from the Yuan dynasty record actions described as "stamping," "advancing forcefully," and "circling" within the structured contexts of ritual and ceremonial practice associated with social status. These accounts indicate that *devsekh* is not merely an aesthetic movement but functions as a **social and cultural code** through which embodied meanings—relating to hierarchy, collective identity, and ritual efficacy—are generated and communicated.

Aims and Research Questions

This article approaches ***devsekh*** through the theoretical intersection of movement studies, anthropology, and performance studies, with the aim of elucidating the relational dynamics between **body, ground, and the composite environment** that emerge through this movement. By situating *devsekh* at the convergence of embodied technique, ritual performance, and environmental engagement, the study seeks to articulate how foundational movements operate as sites of meaning production within Mongolian dance traditions.

The article is guided by the following research questions:

1. If *devsekh* is understood as a bodily technique and a cultural semiotic code, what defining features allow it to be identified as such?

2. What performative functions and meanings does circling through stamping enact within liminal ritual contexts?

3. How do traces left upon the ground and the embodied repertoire of movement operate as a living archive that sustains continuity across historical ruptures?

4. In what ways can *devsekh* be understood as a mediating bridge between historical texts (archive) and lived performance practice (repertoire)?

Methodology

This study undertakes a close textual and historical analysis of key sources, including *The Secret History of the Mongols* (annotated edition by Sh. Choimaa, 2015), Rashid al-Din's *Compendium of Chronicles*, and narrative representations found in Yuan-dynasty poetry. Descriptions of actions such as stamping, forceful advancing, and circling are examined within their ritual and ceremonial contexts, with attention to their semantic structure and their association with social status, authority, and collective practice. This approach allows the movement of *devsekh* to be contextualized within historically situated systems of meaning rather than treated as an isolated choreographic gesture.

Theoretical Framework and Conceptual Synthesis

The analysis is informed by an interdisciplinary engagement with key theoretical perspectives, including Marcel Mauss's concept of bodily techniques, Victor Turner's theories of liminality and communitas, Tim Ingold's relational understanding of human–ground interaction, and Diana Taylor's distinction between archive and repertoire, particularly her emphasis on embodied traces that exceed textual inscription. These theoretical frameworks are not applied as parallel interpretations but are brought into dialogue through the analysis of Mongolian dance movement, enabling a comparative and integrative reading of *devsekh* as an embodied, ritualized, and environmentally situated practice.

1. Devsekh and the Concept of "Techniques of the Body" (Marcel Mauss)

Marcel Mauss conceptualizes techniques of the body as socially learned and transmitted practices that are acquired through repetition, imitation, and instruction, often mediated by figures of authority (Mauss 1973: 74). He emphasizes that collective life as a whole functions as a system of bodily training, through which movements are disciplined, coordinated, and continuously reproduced across generations by means of habitual practice and custom (Mauss 1973: 16). In this sense, every cultural use of the body is shaped by education, which Mauss understands in close relation to imitation. Although individuals may differ in their capacity to imitate, they nonetheless pass through the same educational processes, learning to embody socially established movement sequences and kinetic relations. Such transmission is guided particularly by the imitation of socially respected or authoritative figures, through whom bodily practices acquire legitimacy and continuity (Mauss 1973: 75–76). Mauss developed this theoretical framework through observations ranging from individual gait to complex forms of collective movement, a perspective that provides a useful lens for interpreting the Mongolian practice of stamping and circling while dancing around the sacred tree.

From Mauss's perspective, *devsekh* can be understood as a form of habitual synchronous movement. Synchrony here refers to actions that are temporally aligned—movements that begin and end together, follow a shared rhythm, and unfold through a common sequential structure. This collective dimension is evident in *The Secret History of the Mongols*, which describes the enthronement of Qutula Khan as an event in which people "stamped until their sides pressed together and their knees grew weary" while circling the sacred tree at Khorkhonag. Such an account points not to an individual dance, but to a mass performance in which participants moved together in rhythmic unison. Read through Mauss's theory, this episode illustrates how *devsekh* operates as a socially trained bodily technique, characterized by collective synchronization and repeated downward force, and embedded within a shared system of meaning that is realized through coordinated physical action rather than individual expression.

To further translate these ideas into practice, it is necessary to consider the sensory and affective experiences that emerge when people dance together. The first condition of collective cohesion is the alignment of bodies through a shared rhythm. Once performers submit to a common tempo, bodily movement begins to acquire order and coherence. As participants are guided to perform the same movement in unison, they become increasingly aware of one another, adjusting their actions in response to the collective. As synchronization stabilizes, participants often experience a sense of calm and pleasure, accompanied by a growing trust in those with whom they share the movement. In this process, bodily coordination fosters not only physical order but also affective alignment, transforming individual bodies into an integrated collective.

In the Mongolian context, the movement goal described as "stamping until the ground sinks" reflects a form of bodily exertion well suited to a cultural ethos shaped by martial strength and assertiveness, while simultaneously maintaining a balance between physical and emotional force. When *devsekh* is performed with unified downward force, the ground is compressed and visibly marked, producing a tangible result that in turn motivates the performers and reinforces the movement's significance. In *The Secret History of the Mongols*, the act of stamping and circling following the enthronement of a new khan symbolizes internal cohesion within the circle, rhythmic convergence, and the emergence of a shared emotional intensity. Similar practices following Qubilai Khan's military victories—when soldiers danced collectively around the sacred tree to proclaim triumph—demonstrate how such movement articulates social norms through embodied action. As Mauss observes, movement is never neutral; it is always socially meaningful, distinctive, and invested with collective value (Mauss 1973: 75–76). Read in this light, *devsekh* functions as a socially trained bodily technique through which communal authority, unity, and affective force are physically enacted.

The body is not merely a moving physical object but a technical instrument shaped through social and cultural processes. As Marcel Mauss argues, an action may be considered a "technique of the body" insofar as it fulfils two fundamental conditions: effectiveness and tradition—that is, the action must demonstrably produce effects and be socially transmitted across generations (Mauss 1973:75–76). From this perspective, the movement of stamping while circling (*devsekh*) can be understood as a bodily technique that has maintained its traditional character over an extended historical span.

Evidence of this continuity can be traced from the *Secret History of the Mongols*, which describes the communal stamping performed during the enthronement of Khutula Khan, through Rashid al-Din's accounts of Qubilai Khan recalling analogous ritual movements more than a century later. Additional corroboration appears in related practices such as the foot-stamping movements found in the Buryat *khatarkha* dance, which is historically linked to hunting rituals. Taken together, these sources indicate that stamping and circling movements constitute a stable and transmitted kinetic practice rather than an episodic or decorative gesture.

Moreover, historical descriptions of repeated forceful stamping—so intense that the ground is said to sink or become hollowed—suggest a movement technique that concentrates bodily weight and force through the feet in a highly structured and habitualised manner. Such descriptions point to a patterned use of gravity, rhythm, and bodily mass that exceed spontaneous movement and instead reflects a codified kinetic system.

When analyzed through Mauss's theoretical framework, *devsekh* emerges as a collectively trained, synchronized, and meaning-bearing movement system characterized by rhythmic organization and controlled distribution of bodily weight. It thus exemplifies a classical case of bodily technique: a socially learned, traditionally inherited, and efficacious mode of movement

through which cultural meanings are enacted and sustained. On this basis, the movement of stamping while circling may be identified as a foundational unit of Mongolian dance vocabulary, providing a theoretical grounding for understanding Mongolian dance not as a set of formal choreographic shapes but as a system structured around shared embodied techniques.

2. Liminality, Communitas, and the Performative Force of Repetitive Bodily Action (Victor Turner)

In Victor Turner's theory of ritual, liminality refers to an intermediate and transitional condition in which established social structures are temporarily suspended and new ones have not yet fully emerged (Turner 1982: 28). During this phase, social hierarchies and status distinctions are provisionally dissolved, and normative rules lose their binding force. Turner describes the communitas that arises in liminal situations as an unmediated form of social relation, in which individuals encounter one another not through institutional roles or social masks but at the level of direct "I–Thou" engagement (Turner 1982: 45). This state generates an experiential sense of equality, freedom, and collective intensity outside the constraints of social structure (Turner 1982: 47). Such communal force is not produced abstractly but is most often embodied through rhythmical movement and sound—chanting, drumming, walking, and other synchronized actions—that reorganize bodily perception and social relation simultaneously (Turner 1982: 29).

Turner further links this embodied collectivity to heightened physiological activation, drawing on the concept of "flow" to describe moments in which focused attention on rhythm, structure, and action dissolves the boundary between self and activity, producing a shared peak experience (Turner 1982: 50). In ritual contexts, this state corresponds to what Turner terms ergotropic activation—a condition marked by increased sympathetic nervous activity, accelerated heartbeat and breathing, muscular tension, and the mobilization of bodily energy into movement (Turner 1982: 11–12). Repetitive actions such as stamping, shouting, singing, drumming, and circling bring participants into this intensified bodily state, generating what Turner calls "collective arousal." Mongolian practices of stamping and circling dance create precisely such a liminal space, temporarily neutralizing status differences and shifting participants into an embodied condition of communitas. The repeated downward force of the feet, shared rhythmic alignment, and synchronized vocalization cause bodily responses to converge, transforming individual exertion into a collective physiological and affective surge. Through this heightened state, ritual meanings—such as oaths of loyalty, communal bonds, and declarations of victory—are not merely symbolized but physically inscribed in the body, as illustrated by mass stamping dances performed during the enthronement of Qutula Khan and the celebration of Qubilai Khan's military victories.

3. Devsekh as Embodied Memory: Archive, Repertoire, and the Living Ground

In *The Archive and the Repertoire* (2003), Diana Taylor distinguishes between the archive and the repertoire as two modes of cultural transmission. While the archive consists of texts, documents, and written records, the repertoire refers to forms of knowledge stored and enacted in the body—that is, embodied memory (Taylor 2003: 36). Many crucial dimensions of culture, including memory, meaning, and affect, are not fully captured in written form but are preserved and transmitted through movement, rhythm, vocal patterns, and collective action (Taylor 2003: 20–23). Repetitive bodily practices generate durable traces that are retained in sensory experience, corporeal memory, and habitual movement, thereby forming a repertoire that remains alive, re-enactable, and continuously reconstituted in performance (Taylor 2003: 51–55). In this sense, the repertoire differs fundamentally from the archive in that it persists not as a fixed record but as a living, bodily mode of knowledge.

Viewed through this framework, *devsekh* functions as an embodied form of memory through both the traces it leaves on the ground and the rhythmic patterns retained in the body. Written sources such as *The Secret History of the Mongols* and Rashid al-Din's *Compendium of Chronicles* record *devsekh* as a named action within the archive, yet the movement's lived significance has been sustained through corporeal memory and performative repetition. The bodily enactment of stamping—its weight, rhythm, and force—generates what may be described as performative traces within the repertoire, allowing *devsekh* to bridge historical discontinuities. Through this dynamic interaction between archive and repertoire, the movement continues to transmit meaning not solely through textual reference but through embodied practice.

The Living Contract with the Ground. Tim Ingold conceptualizes the environment not as a passive backdrop but as an active participant in human life, emphasizing that humans and their surroundings exist in a relationship of mutual engagement rather than separation (Ingold 2000: 16, 18–19, 424). Humans move with the ground, wind, and trees, enter their rhythms, leave traces, read those traces, and reconnect through ongoing interaction (Ingold 2000: 11). The ground itself, in this view, is an agentive presence rather than inert matter (Ingold 2000: 110). In *devsekh*, the dancer's body transfers weight downward, causing the ground to vibrate; rhythm is transmitted into the earth and returned through sound, resistance, and tactile sensation. These sensory exchanges exemplify Ingold's notion of dwelling and enskilment, in which skill emerges through continuous engagement with the environment.

Through repeated stamping, the marks left on the ground and the rhythms retained in the body become performative traces in Taylor's sense, forming a living relationship between body and land. This interaction resonates with Mongolian cosmological perspectives that regard the land and natural elements as animate and relational. A passage in Rashid al-Din's *Compendium of Chronicles*, in which Qubilai Khan vows to adorn a sacred tree and dance if he achieves victory, illustrates this worldview. The conditional phrase "if I defeat the enemy" signals a form of negotiated commitment with

the landscape, one that treats the earth not as an object but as a participant in ritual exchange. The practice of stamping and circling around the sacred tree can thus be understood as a form of "living contract" with the ground—an embodied agreement through which human intention, bodily action, and the animate environment are ritually bound together.

4. Historical Sources and Analysis

In *The Secret History of the Mongols*, Section 57 describes the enthronement of Qutula Khan as a collective ritual event in which the people of Hamag Mongol and the Tayichiud gathered at Khorkhonag by the Onon River and "stamped in celebration, rejoicing together." The text recounts that after raising Qutula as khan, they "stamped until their sides pressed together and their knees grew weary" while circling the sacred tree (Choimaa 2015: 28). The expressions "until their sides pressed together" and "until their knees grew exhausted" indicate that stamping was not a light or decorative gesture, but a movement characterized by repeated downward force directed toward the ground, requiring physical endurance and sustained exertion.

This description suggests that *devsekh* functioned as a bodily practice structured around rhythmic repetition and collective force. Performed during the enthronement ritual, the movement brought participants into synchronized action, aligning bodies within a shared tempo and spatial configuration. In this liminal context, the collective stamping and circling enacted the emergence of a new social structure—the authority of the khan—through performance rather than proclamation alone. The ritual movement thus operated as a performative realization of political order, in which communal rhythm and embodied coordination transformed social transition into a physically enacted reality.

Rashid al-Din's Compendium of Chronicles and the Performative Declaration of Victory. In Rashid al-Din's Compendium of Chronicles (2002: 210–213), a vivid account describes Qubilai Khan's participation in a military campaign against the Merkid people. While traveling, Qubilai dismounted at a tree, offered prayers to ancient deities, and vowed that "if I defeat the enemy, I will adorn this tree with garments of many colors." After being granted victory, he fulfilled this vow and, together with his soldiers, performed a stamping dance beneath the tree as an act of thanksgiving and offering. The chronicle notes that through their repeated forceful stomping, the ground around the tree became visibly sunken, "pressed down to a depth of about one span," attesting to the intensity and repetition of the movement.

This episode demonstrates that devsekh functioned not merely as celebratory movement, but as a performative act that proclaimed success and ritually affirmed victory. The conditional vow—"if I defeat the enemy"—frames the subsequent dance as a fulfillment of a reciprocal exchange with the landscape, while the stamping itself physically inscribes triumph onto the ground. The traces left by the repeated downward force serve simultaneously as markers of territorial assertion and as performative residues within a living repertoire. In this way, devsekh operates as a declaration enacted through bodily action, where military success, ritual obligation, and embodied memory converge. The sunken ground becomes both evidence of collective exertion and a material imprint through which victory is remembered and transmitted beyond the moment of performance.

Yuan Dynasty Poetry and the Aestheticization of Devsekh. The transformation of devsekh from ritual and military practice into an aestheticized form is further evidenced in Yuan dynasty poetry. The Harluut-descended poet Naixian (乃贤, 1309–1368), renowned for his mastery of literary expression, refers explicitly to stamping dance as "song and dance with stamping feet" (ta ge, 踏歌) in the fourth poem of his five-part cycle Songs of the Frontier (Sai shang qu wu shou, 《塞上曲五首》). This poem vividly evokes the sensory landscape of steppe life during the Yuan period, simultaneously conveying taste, smell, sound, and movement through dense and animate imagery. Rather than isolating movement as a purely visual form, Naixian situates bodily action within a multisensory environment shaped by rhythm, sound, and collective presence.

Within the festive space of military celebration, the poem depicts soldiers singing and dancing with stamping feet in synchrony with the sounds of whips and drums. Here, bodily movement and vocal expression are tightly integrated, and rhythmic coordination transforms collective exertion into a performative spectacle. Through poetic representation, the transmission of devsekh shifts from embodied ritual practice into an artistic mode of display, marking its expansion into court cultural space while retaining its kinetic and rhythmic foundations. In this literary context, stamping emerges as a stable semiotic code that moves fluidly across everyday pastoral life, military triumph, and elite aesthetic expression. The poem thus demonstrates how devsekh, while rooted in embodied practice, becomes legible as a cultural form within textual and artistic media, reinforcing its status as a living repertoire capable of adaptation without loss of structural coherence.

The Poem (Original Text) and Analytical Translation:

Naixian, *Songs of the Frontier* (《塞上曲五首》), Poem IV

"马乳新挏玉满瓶
沙羊黄鼠割来腥
踏歌尽醉营盘晚
鞭鼓声中按海青"

Analytical Translation

Freshly churned mare's milk fills jade cups,
The raw scent of steppe game freshly cut with knives.
Stamping feet sing and dance, drunken until dusk at the camp,
Amid the crack of whips and the beat of drums, hawks are held in hand.

5. Brief Linguistic Note

The kinetic and semantic stability of *devsekh* is further supported by lexical evidence. In the Mongolian–Chinese glossary *Hua Yi Yi Yu* (華夷譯語), compiled in 1389 (Hongwu 15) under the supervision of Huo Yuance, the Mongolian term is transliterated into Chinese characters as 德毕勒苏勒格 (*debiləsülegə*) and defined as "repeatedly stamping the ground with the feet in dance." This early lexicographic record already emphasizes repetition, downward force, and dance-related movement as core semantic components of the term.

Additional confirmation appears in modern Mongolian linguistic sources. In *The Etymological Dictionary of Mongolian Words*, Setsentsogt (1988: 1780) traces the root *tab*, referring to a striking or closing sound, and *tabara*, meaning "to jump, leap, or stamp with the feet." Similarly, *The Comprehensive Dictionary of the Mongolian Language* defines the verb as forcefully striking the ground or objects beneath the feet with the sole, often involving lifting and driving the foot downward with force. Together, these definitions confirm that the movement's kinetic characteristics—impact, repetition, and downward exertion—are embedded at the lexical level. This lexical–kinetic correspondence provides a dual validation across archive and repertoire, demonstrating how written language and embodied practice reinforce one another in the transmission of *devsekh* as a culturally stable movement form.

Conclusion

This study has argued that devsekh should be understood as a foundational movement of Mongolian dance, not merely as a symbolic gesture but as a bodily technique through which rhythm, force, and spatial organization generate cultural meaning. By tracing recurring physical actions—stamping the ground, sustained downward pressure, circular motion, and collective synchronization—across historical texts, poetic representations, and performance contexts, the analysis demonstrates the structural continuity of devsekh in ritual, pastoral, military, and court settings.

Rather than separating archival description from embodied practice, the article has shown that devsekh operates simultaneously as physical action and living repertoire. Written records, poetic language, and lexical definitions preserve the movement within the archive, while material traces on the ground and durable patterns held in corporeal memory sustain its transmission through performance. In this sense, devsekh mediates between textual, linguistic, and bodily forms of knowledge, allowing movement to persist across historical discontinuities.

Positioning devsekh as an analytical unit highlights the importance of movement-based approaches to Asian dance studies. By foregrounding physical force, spatial marking, collective embodiment, and human–land interaction, this study demonstrates how foundational dance movements function as sites where social order, communal intensity, and embodied knowledge converge. Such an approach contributes to broader discussions on dance documentation by showing how bodily techniques and living repertoires, rather than textual records alone, sustain the vitality of movement traditions.

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BIOLOGICAL SCIENCES

CAMPANULACEAE JUSS. IN THE FLORA OF NAKHCHIVAN: TAXONOMIC REVIEW, ECOLOGICAL ADAPTATIONS, AND PRACTICAL SIGNIFICANCE

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Abstract

Nakhchivan Autonomous Republic is one of the regions distinguished by its rich flora, and *Campanulaceae* Juss. family occupies a special place on its flora. As a result of expeditions conducted in 2011–2025, more than 600 herbarium specimens were collected from various mountainous zones, GPS coordinates and heights were recorded. As a result of studies conducted using floristic, systematic, ecological and geobotanical methods, it was determined that the family is represented by 3 genera, 20 species and 6 variations in Nakhchivan flora, which constitutes 52.63% of the species distributed in Azerbaijani flora. The species are divided into mesophyte, xerophyte and intermediate groups according to their relationship to humidity, and heliophyte and facultative heliophyte according to their relationship to light. Biomorphological analysis showed that perennial herbs predominate. In terms of vertical zonality, it was found that species are unevenly distributed in the foothills, middle and high mountain zones. As a result of the research, 8 Caucasian endemic and 7 rare species were identified, their distribution areas were specified and included in the "Red Book". Due to their decorative properties, 11 species were recommended for use in ornamental gardening and landscaping. This study presents the first extensive analysis of the systematic and bioecological characteristics of the *Campanulaceae* family in the flora of Nakhchivan AR.

Keywords: *Campanulaceae* Juss.; Floristic Diversity; Taxonomy; Bioecology; Vertical Zonation; Endemic Species; Rare Plants; Conservation; Ornamental Plants

INTRODUCTION

Azerbaijan's varied landscapes—from the Greater and Lesser Caucasus to the Kur-Araz lowland and Caspian coast—harbor a rich diversity of living organisms. [*Iskender, E.O., & Jafarzade, S.A., 2015; Jafarzadeh, S., & Iskender, E., 2024; Bakhshaliyeva, & Muradov, P.Z., 2026; Yadi, M., & Milani, M., 2018a; Yadi, M., & Milani, M., 2018b; Mammadov, E., & Aliyeva, I.M., 2025; Elshad, G., & Kamala, A., 2020; Gurbanov, E.M., & Elkordy, A., 2019; Humira, H., 2021; Gurbanov, E.M., & Huseynova, H.Z., 2021; Gurbanov, E.M., & Huseynova, H.Z., 2023; Mammadova, F., 2025; Sabuka, N., & Fidan, M., 2022; Mammadova, F., 2026*]. Environmental pressures such as desertification, mining, and salinization further affect negatively these ecosystems [*Mikayilov, A., & Amrahov, E.A., 2023; Khalilova et al., 2025; Khalilova, L.S., 2023; Khalilova, L.S., 2022; Gurbanov, E.M., & Asadova, K.A., 2024*].

Within the broader framework of Azerbaijan's floristic diversity, the *Campanulaceae* family occupies a significant position. Species of *Campanulaceae* family are widely distributed across mountainous and meadow ecosystems, where they serve both ornamental and ecological functions. Their sensitivity to soil and climatic conditions makes them valuable bioindicators of ecosystem health. This ecological responsiveness underscores their importance not only in documenting biodiversity but also in guiding conservation-oriented measures.

Accordingly, the study of *Campanulaceae* in Azerbaijan contributes to a deeper understanding of floristic richness while providing a scientific basis for strategies aimed at preserving ecological stability and ensuring sustainable management of natural resources.

Nakhchivan Autonomous Republic is one of the regions distinguished by its rich flora diversity. In this rich floristic spectrum, the family *Campanulaceae* Juss. occupies a unique place. Representatives of the family are widely used in the landscaping of parks and alleys due to their decorative properties, and entomophilous species are also considered an important food source for polylectic and oligolectic bees [*Nasirova, A.S., Talibov, T.H., 2015; 2016*].

Although general information about the family was provided in previous studies, its systematic composition, role in phytocenoses and effective use have not been studied in detail. Therefore, floristic analysis of the *Campanulaceae* family in the flora of Nakhchivan Autonomous Republic, investigation of its bioecological characteristics, identification of rare species, specification of their geographical areas, as well as development of ways of its protection and effective use are of great scientific and practical importance. The main purpose of the study is to study the distribution of *Campanulaceae* family in the biodiversity of the Nakhchivan Autonomous Republic, its bioecological characteristics, role in phytocenoses and taxonomic composition, and to develop recommendations for the protection and use of species of scientific and practical importance [*Nasirova, A.S., 2012*].

The name *Campanula* appeared before Linnaeus and is associated with the shape of the plant crown. For the first time, K. Linnaeus described many species of

the genus in his work "Species Plantarum" (1753). In later periods, A. Decandol's work "Monographie des *Campanulees*" (1830) was a new stage in the study of the genus. In the 19th–20th centuries, various aspects of the genus were highlighted in the works of F.G. Bartling, S.L. Endlicher, H.E. Bayon, E. Warming, S. Shenlanda, Ledebur, K. Koch, F.I. Rupprecht, E. Boissier, A.L. Kharadze, A.V. Fomin, A.A. Kolakovsky and other researchers. In recent years, taxonomic studies conducted by V.P. Viktorov (2006), as well as publications on the flora of Turkey, Iran, Georgia and the USSR, have expanded ideas about the systematics of the genus. In Azerbaijan, information about the *Campanulaceae* family was provided in studies conducted by A.A. Grossheim (1935, 1961), A.M. Askerov (2006), T.H. Talibov (2002) and A.Sh. Ibrahimov (2005), [*Nasirova, A.S., 2012; 2013a; 2013b; 2014a; 2014b; 2015a; 2015b; 2015c; 2015d; 2016a; 2016b; 2017a; 2017b; 2018a; 2018b; 2020*].

MATERIAL AND METHODS

The object of the study is the *Campanulaceae* Juss family. The material used was the *Campanulaceae* family species collected during field research in various mountainous zones of the Nakhchivan AR. As a result of the expeditions conducted in 2011–2025, more than 600 herbarium specimens were collected, GPS coordinates and heights were recorded.

Floristic, systematic, ecological, geographical and geo-botanical methods were used, the specimens were herbariumized using standard methods. Morphological differences were determined by microscopic analysis. During the assignment, A.A. Grossheim, A.A. Kolakovsky, L.V. Lazarev, "Flora USSR", "Flora Europae", flora of Georgia, Iran and Turkey, as well as the international code of botanical nomenclature and other sources were used.

Systematic floristic surveys were carried out during the vegetation seasons (April–September) over multiple years. Standard transect and quadrat methods were applied to ensure representative sampling [*Kent, 2012*]. Voucher specimens of all encountered *Campanulaceae* taxa were collected, pressed, and deposited in the Herbarium of the Institute of Botany, AMEA Nakhchivan Branch. Diagnostic morphological traits (leaf shape, corolla structure, calyx morphology, fruit type, seed characteristics) were recorded using stereomicroscopy and digital calipers. High-resolution photographs were taken for comparative analysis [*Radford et al., 1974*]. Identification was performed using regional floras [*Flora of Azerbaijan, Grossheim, 1952; Flora of the USSR, Komarov, 1934–1960*] and specialized monographs on *Campanulaceae* [*Lammers, 2007*]. Synonymy and taxonomic updates were cross-checked with international databases [*The Plant List, 2013; World Flora Online, 2024*]. Distribution maps were generated using GIS software (ArcGIS/QGIS) based on GPS coordinates of collection sites [*Longley et al., 2015*].

RESULTS

Based on literature data and the results of field research, a number of changes have been identified in the taxonomic composition of the *Campanulaceae* family in the flora of Nakhchivan AR. Although 23 species of the family were recorded in previous studies, as a result of the research conducted, the total number of species has decreased to 20 with the synonymization of some species and reduction to the level of variation [*Nasirova, A.S., 2014b; 2018a; 2017a*]. Thus, the family is represented by 3 genera, 20 species and 6 variations in the flora of autonomous republic.

- Genus *Campanula* L. – 15 species (*C. glomerata, C. latifolia, C. rapunculoides, C. bononiensis, C. sclerotricha, C. daralaghezica, C. zangezura, C. bayerniana, C. coriacea, C. massalskyi, C. saxifraga, C. tridentata, C. karakuschensis, C. propinqua, C. stevenii*)
- Genus *Asyneuma* Griseb. et Schenk – 4 species (*A. amplexicaule, A. campanuloides, A. rigidum, A. pulchellum*)
- Genus *Michauxia* L. Her. – 1 species (*M. laevigata*)

The geographical-areal elements and types of the species of *Campanulaceae* have been determined. In the flora of the Nakhchivan AR, species of *Campanulaceae* family belong to: 7 geographical-areal elements (Iran-Turanian – 6 species, Atropatan – 5 species, Europe-Siberia – 3 species, Asia Minor-Caucasus – 2 species, Caucasus – 2 species, Europe-Mediterranean – 1 species, Western Front Asia – 1 species) and 3 geographical-areal types (Boreal, Xerophilous, Caucasus) [*Nasirova, A.S, 2013a; 2013b; 2016b*].

Representatives of *Campanulaceae* family are divided into 4 ecological groups according to their relationship to humidity: mesophytes (8 species), meso-xerophytes (3 species), xero-mesophytes (5 species), xerophytes (4 species). Hygrophytes were not found.

According to their attitude to light, the species are divided into heliophytes (15 species) and facultative heliophytes (5 species).

According to biomorphological analysis, in the classification of I.G. Serebryakov, the basis of the family is perennial herbs (16 species, 80%). Biennial herbs are represented by 3 species (15%), and annual herbs by 1 species (5%).

According to the classification of K. Raunkier, hemicryptophytes constitute the life forms of the family with 19 species (95%), and therophytes by 1 species (5%). Phanerophytes and megaphanerophytes have not been found.

In the Nakhchivan Autonomous Republic, representatives of *Campanulaceae* family are distributed in mountain-xerophyte, meadow, steppe, forest and petrophilous vegetation types. Studies have shown that 4 species (*C. stevenii* Bieb., *C. tridentata* Scherb., *C. latifolia* L., *C. rapunculoides* L.,) form formations and associations. *C. glomerata* L., C. *bononiensis* L., *A. campanuloides* (Bieb. ex-Sims) Bornm., *A. pulchellum* (Fisch. et C.A. Mey.) Bornm., *A. amplexicaule* (Willd.) Hand. -Mazz. species were found as edificatory plants of the meadow vegetation type [*Nasirova, A.S., 2014a; 2018b; 2020; Nasirova, A., Mammadova G., 2026*].

10 species of the representatives of the family [*C. karakuschensis, C. daralaghezica, C. bayerniana, C. coriaceae, C. massalskyi, C. saxifraga, C. sclerotricha, C. propinqua, C. zangezura, Michauxia laevigata*]

were found singly or in small micro-groups in the petrophilous vegetation type [*Nasirova, A., Orujova, A., et al., 2024*].

The complex mountainous relief and continental climate of the Nakhchivan AR have led to the distribution of plants along vertical zonation. As a result of research, 1 species (*C. massalskyi*) has been identified in the low mountainous zone, 1 species (*C. karakuschensis*) in the middle mountainous zone, and 6 species (*C. sclerotricha, C. daralaghezica, C. zangezura, C. saxifraga, C. tridentata, A. amplexicaule*) in the high mountainous zone [*Nasirova, A.S., 2015b*]. The representatives of the family, 10 species (*C. glomerata, C. latifolia, C. rapunculoides, C. bononiensis, C. bayerniana, C. coriacea, C. stevenii, A. campanuloides, A. rigidum, A. pulchellum*) are distributed from the middle mountainous zone to the subalpine zone. *Michauxia laevigata* is found from the foothill zone to the subalpine zone [*Nasirova, A.S., Talibov, T.H., 2014*].

Campanulaceae family is represented by 79 species in the Caucasus, 52 of which are endemic. 8 Caucasian endemics have been identified in the flora of the Nakhchivan AR (*C. bayerniana, C. glomerata subsp. caucasica, C. massalskyi, C. karakuschensis, C. saxifraga, C. daralaghezica, C. zangezura, A. campanuloides*). As a result of the studies, 7 species (*C. latifolia, C. daralaghezica, C. zangezura, C. coriaceae, C. karakuschensis, C. propinqua, A. campanuloides*) were included in the "Red Book" of Nakhchivan Autonomous Republic and Azerbaijan Republic based on various criteria [*Nasirova, A.S., 2015a; Iskender, E.O., & Jafarzade, S.A., 2015*].

11 species of the *Campanulaceae* family (*C. glomerata, C. latifolia, C. rapunculoides, C. daralaghezica, C. zangezura, C. bayerniana, C. coriacea, C. tridentata, C. karakuschensis, C. stevenii, Michauxia laevigata*) can be widely used in ornamental gardening and landscaping due to their decorative properties [*Nasirova, A.S., 2016a; 2015c; 2015d, 2017b*].

CONCLUSION

The systematic composition, bioecological characteristics, phytocenological groupings and use of the *Campanulaceae* family in the flora of the Nakhchivan AR were investigated by us for the first time. Thus:

For the first time, 20 species, 6 variations belonging to 3 genera of the family were identified in the flora of the Nakhchivan AR, which constitutes 52.63% of the family spread in the flora of Azerbaijan. As a result of the geographical-areological analysis, it was determined that, the plants of the family belong to 7 geographical areal elements and 3 geographical-areal types. As a result of the ecological analysis, it was determined that, the species are divided into 4 groups according to their relationship to humidity (mesophytes - 8 species, meso-xerophytes - 3 species, xero-mesophytes - 5 species, xerophytes - 4 species). According to their relationship to light, the species are divided into groups of heliophytes (15 species) and facultative heliophytes (5 species). According to bio-morphological analysis, perennial grasses (16 species), biennial grasses (3 species), annual grasses (1 species) predominate; according to Raunkier classification, hemicryptophytes (19 species) and therophytes (1 species) were identified. The distribution pattern in vertical zonation was studied, and it was determined that the species were unevenly distributed in the foothills, middle and high mountain zones. For the first time, new plant groups of 5 species and 37 new distribution areas for 12 species were discovered. The current status of 7 rare species included in the Red Book was studied, and their distribution areas were specified.

Due to their decorative properties, we recommend the use of *C. glomerata, C. latifolia, C. rapunculoides, C. daralaghezica, C. zangezura, C. bayerniana, C. coriacea, C. tridentata, C. karakuschensis, C. stevenii* and *Michauxia laevigata* species in ornamental gardening and landscaping.

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IMPACT OF CLIMATE CHANGE ON THE GROWTH DYNAMICS OF NATIVE TREE SPECIES (*PINUS SYLVESTRIS* - IN AZERBAIJAN)

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Abstract

This study investigates the impact of climate change on the growth dynamics of *Pinus sylvestris* in Azerbaijan through dendro-climatological analysis covering the period 1900–2026. Using tree-ring chronologies, climate data, and statistical methods (EPS, response function analysis, moving correlation analysis, SEA), the research reveals species-specific and time-dependent growth responses. Results demonstrate that *Pinus sylvestris* growth is positively correlated with winter temperatures (January–March), while precipitation shows no significant effect. Drought years (e.g., 1907, 1921, 1976, 2003, 2019) caused notable reductions in ring width, but recovery occurred in subsequent years, indicating high adaptive potential. The findings highlight that moderate winters stimulate growth by reducing soil frost depth and enhancing photosynthetic activity, whereas prolonged summer droughts remain a limiting factor. Overall, *Pinus sylvestris* exhibits relative resilience compared to other conifers (e.g., *Picea orientalis*), positioning it as a potentially sustainable species under projected climate scenarios. These results provide a scientific basis for forest management strategies, biodiversity conservation, and adaptation planning in Azerbaijan's mountainous ecosystems.

Keywords: Climate change, Dendro-climatology, *Pinus sylvestris*, Growth dynamics, Tree rings, Adaptation, Azerbaijan forests

INTRODUCTION

Climate change is considered one of the greatest challenges to the sustainability of ecosystems and the stability of agricultural production in modern times. As a result of increasing atmospheric temperature, changing precipitation patterns, and intensifying droughts and floods, biodiversity is weakening, soil fertility is decreasing, and freshwater resources are limited. Although increasing carbon dioxide concentration increases the rate of photosynthesis and creates a "fertilization effect" in plants, it weakens the nutritional quality of products, causing a decrease in protein and mineral content. These processes affect the phenological cycles of plants, limiting their reproductive capabilities, accelerating the spread of pests and diseases, reducing the population of pollinating insects, and ultimately creating instability in agricultural production *(Garibov & Hebilov, 2021).*

The impact of climate change is more pronounced in various ecosystems of Azerbaijan, especially in local tree species. Over the past 120 years, the reduction of forest areas, increased soil erosion, and the gradual lowering of the upper limits of forests have led to a disruption of the ecological balance. Dendrochronological studies conducted on the Hyrcanian flora show that, the development of rare and old trees has sharply weakened in recent decades, and forest fires have led to the extinction of endemic and relict species *(Gurbanov, H., 2024)*. In this context, the study of the growth dynamics of the *Pinus sylvestris* species is of particular importance, since this species is distinguished by its sensitivity to anomalous temperature, drought and frost events. Scientifically based studies are important for assessing the adaptive capabilities of local tree species and protecting biodiversity.

LITERATURE REVİEW

Changes in global temperature and precipitation regimes are considered to be among the main factors that have a significant impact on plant development processes and growth *(IPCC, 2021; Briffa et al., 1998).* According to various projection models, continued warming until mid-century will increase the variability of the water cycle, create instability in precipitation amounts, and intensify drought events. The literature shows that, although increasing temperatures and lengthening the growing season stimulate tree growth in some cases, decreasing precipitation and its uneven distribution over the annual cycle can weaken growth rates *(Allen et al., 2010).* Projections for Azerbaijan confirm rapid warming accompanied by reduced summer precipitation, which increases the risk of long-term droughts, storms and floods in forest ecosystems. These changes can lead to shifts in species composition, a decrease in biomass production, and disruption of ecosystem stability.

Studies have shown that, the impact of climate change on Azerbaijan's vegetation and agricultural systems has been multifaceted:

The increase in atmospheric CO_2 concentration has created a "fertilization effect" in plants, increasing the rate of photosynthesis and increasing productivity. However, this rapid growth has been accompanied by a weakening of wood quality and a decrease in nutritional value. These results have also been confirmed in international studies, which show that, the structural quality of plants weakens under high CO_2 conditions *(Myers et al., 2014).*

A 3–17% decrease in minerals such as protein, zinc and iron has been recorded in cereal crops (wheat, barley, oats, rice). These changes have had a negative

impact on the quality of feed in livestock farming, as well as human nutrition. Similar results have been observed in studies conducted in other regions.

As a result of the increase in temperature, premature yellowing of leaves, shifting of flowering periods and weakening of reproductive capabilities have been recorded in many tree and shrub species. This phenomenon was clearly manifested in observations conducted in the Central Botanical Garden and on the Absheron Peninsula.

Heat waves and increased humidity accelerated the spread of pests and diseases, reduced the population of pollinating insects, and weakened the reproductive success of plants *(Allen et al., 2010)*. Cases of infection with the olive leafhopper (*Saissetia oleae*) in olive trees (*Olea europaea*) have proven that, climate change increases the susceptibility of plants to diseases.

Increased droughts and floods have weakened soil fertility and negatively affected the growth rate of plants by reducing the reliability of irrigation water. Sea level rise has intensified the processes of salinization and waterlogging in coastal soils.

Dendrochronological studies conducted on the Hyrcanian flora have shown a sharp decline in the growth rate of rare and old trees in the last 20–30 years. Forest fires have caused serious damage to biodiversity and led to the destruction of beneficial entomofauna living in the fertile soil layer *(Aliyev, 2019).*

Literature analysis shows that, climate change has had both positive (CO_2 fertilization effect, acceleration of photosynthesis) and negative (decrease in food value, phenological disturbances, increase in pests, weakening of soil and water resources, forest fires) impacts on the flora and agricultural systems of Azerbaijan. These results are consistent with regional observations as well as international studies and prove that, Azerbaijani ecosystems are at high risk against the background of climate change.

Tree-ring analysis is considered an important methodological approach to study the impacts of climate change. Dendro-climatological studies show that, changes in temperature and water regimes cause species- and site-specific variations in ring width, which allows assessing the growth behavior of trees *(Speer, 2010; Vaganov et al., 2006).* Tree rings serve as a natural archive for paleoclimate reconstruction and have been widely used since the early 20th century to reconstruct temperature, precipitation variability and drought *(Fritts, 1976; Cook & Kairiukstis, 1990).* Studies on the response of different species to climate have yielded conflicting results, with some species being selected for their sensitivity to drought, while others have shown more variability. Studies in this context are important for understanding the long-term effects of climate change on forest productivity and carbon sequestration.

MATERIAL AND METHODS

This study was conducted to study the impact of climate change on the growth dynamics of native tree species in Azerbaijan. The study was carried out in selected forest areas in the Greater Caucasus, Lesser Caucasus, Talysh Mountains and Nakhchivan regions.

Pinus sylvestris was selected as the main species for the study. This species is naturally distributed in various regions of Azerbaijan - Guba, Gusar, Balakan, Goygol, Tovuz, Shamkir, Agstafa, Shamakhi, Sheki, Gabala, Gadabay, Murovdagh range and Nakhchivan Autonomous Republic. Due to its rare and limited range, it was included in the "Red Book" of Azerbaijan. The creation of new reserves is considered important for the protection of this species, which reproduces mainly generatively.

In total, 12 dominant trees were selected (3 trees from each site). The selection of dominant trees was aimed at minimizing the impact of micro-environmental factors - competition for light, water and nutrients. The tree cores were taken at a height of 1.3 m, at a 90° angle, using a special borer tool. The samples were transported to the laboratory, dried, polished, and the rings were clearly visible.

The study areas represented typical forests of the region. The annual mean temperature was 8.6 °C and the annual precipitation was approximately 665 mm. The soils were moderately fertile, low in clay content and moderately humid. Climatic parameters were taken from the database of the Azerbaijan National Meteorological Service covering the years 1900–2026. Temperature and precipitation parameters were extracted from raster maps with a resolution of 1 km × 1 km, and the parameters corresponding to the location of each tree were selected and summarized at the site level.

The width of the rings was measured using the LINTAB system and the TSAP-win program, and the results were checked using the COFECHA program *(Gauli et al., 2022).* The standardization of the rings was carried out using the dplR package, long-term trends were extracted, and high-frequency changes were retained *(Buras, 2017).* The chronology was based on annual averages, and statistical parameters such as EPS, Rbar and Gleichläufigkeit were calculated. Only years with a strong signal (EPS > 0.85) were included in the analysis.

Long-term changes in temperature and precipitation parameters were analyzed using local polynomial regression in R. The relationship between ring chronology and climate parameters was assessed using response function analysis and moving correlation analysis. This approach allowed us to track the changes in the growth response of species over time.

The impact of drought years was investigated using the Superposed Epoch Analysis (SEA) method. The Standardized Precipitation Evapotranspiration Index (SPEI) was used as a drought indicator. SPEI was calculated for the years 1900–2026, with values below -1.5 classified as moderate, and values below -1.5 as severe drought years.

The selected methods allowed for a comprehensive study of the impact of climate change on the growth dynamics of local tree species. This approach is of great importance both in terms of assessing the risks of ecological imbalance and in terms of forming scientific foundations for the protection of biodiversity.

RESULTS

In different regions of Azerbaijan, an increase in temperature indicators and a decrease in precipitation indicators were observed during the period 1900–2026.

The average annual temperature increased by approximately 0.4–1.3 °C, and annual precipitation decreased by 7%.

The analysis results showed that, the growth dynamics of the *Pinus sylvestris* species demonstrate a specific and time-varying sensitivity to climate variability. During the study, the chronology of tree rings for the *Pinus sylvestris* species was as follows:

A 121-year chronology was established for the *Pinus sylvestris* species (1900–2020). The average ring width for the *Pinus sylvestris* species (2.06 mm). Statistical indicators (Mean sensitivity = 0.24; Series intercorrelation = 0.541; EPS = 0.885; Gleichläufigkeit = 0.634) confirmed the reliability of the climate signals. The EPS (expressed population signal) values were higher than 0.85 for the species, confirming a strong overall signal.

Analyses based on climate-growth relationships showed that, the response function analysis between ring width and climate variability showed that, *Pinus sylvestris* growth was mainly positively correlated with winter temperature (January, February, March) *(Gauli et al., 2022).* This suggests that, mild winter conditions stimulate growth. The relationship with precipitation was not statistically significant *(Babst et al., 2014).*

According to the analyses, January, February and March temperatures were the climatic variables with the strongest influence on growth for *Pinus sylvestris*. Since 1911, tree growth has responded positively to the average temperature of January, February and March, and this trend has been strengthened in recent years. The effect of April temperature on growth was significant between 1916 and 1980, but weakened and decreased over time.

A moving correlation analysis confirmed that, the positive relationship with January–March temperature has strengthened since 1911. The effect of April temperature has weakened and lost significance after 1980.

A significant decrease in *Pinus sylvestris* ring width was recorded in drought years (e.g. 1907, 1921, 1976, 2003, 2019) as determined by the Standardized Precipitation Evapotranspiration Index (SPEI). However, this effect did not persist in subsequent years.

Pinus sylvestris grows better in mild winter conditions and is relatively less sensitive to precipitation. Despite the reduction in growth during drought years, the species has a high adaptive potential *(Gauli et al., 2022; Vaganov et al., 2006).* These results indicate that, *Pinus sylvestris* can be considered a relatively resilient species in Azerbaijani forests against the backdrop of climate change.

DISCUSSION

The average ring width of *Pinus sylvestris* species decreased over the years. This result is consistent with previous studies. EPS for the species, serial inter-correlation and other statistical indicators confirmed a strong general ecological signal.

The analyses showed that, the climate-growth relationship is species-specific and shows variability over time. The growth of *Pinus sylvestris* species was mainly stimulated by the increase in temperature in January, February and March of this year. This is explained by the decrease in deep soil freezing in mild winter conditions and the creation of a favorable environment for photosynthesis.

The average annual temperature in different regions of Azerbaijan has increased by approximately 1.3 °C since 1900. The increase in temperature in winter months had a positive effect on the *Pinus sylvestris* species.

In general, the increase in mild winters stimulates the growth of *Pinus sylvestris* species. These results provide an important scientific basis for assessing the adaptive potential of species and formulating forestry strategies against the background of climate change.

The results prove that, climate change has a direct impact on the growth dynamics, nutritional quality, phenological cycles, and ecological stability of Azerbaijan's vegetation. Strengthening adaptation measures, protecting biodiversity, and implementing sustainable agricultural technologies are considered necessary to mitigate these impacts.

CONCLUSION

The conducted dendro-climatological analyses showed that, climate-growth relationships are species-specific and show variability over time. *Pinus sylvestris* species showed better growth performance in mild winter conditions, especially when temperatures increased in January, February and March stimulated their development.

According to climate projections, temperatures are expected to increase in Azerbaijan and precipitation will decrease in summer months. Although *Pinus sylvestris* may continue to benefit from mild winters under these conditions, this process will negatively affect the growth and productivity of species that are more sensitive to summer drought.

Overall, the study shows that, the growth response of tree species against the background of climate change is specific, variable and unstable. These results provide an important scientific basis for assessing the sustainability of forest ecosystems, determining the adaptive potential of species and formulating future forestry strategies.

In the mountainous and foothill forests of Azerbaijan (Guba, Sheki, Nakhchivan regions), *Pinus sylvestris* species is found in both natural and introduced conditions. Regional observations show that, in the northern regions, mild winter conditions increase ring width, while growth is weakened in years with severe frosts. Although the annual amount of precipitation does not directly affect growth, a decrease in ring width is observed in years of prolonged drought (especially in the Nakhchivan and Ganja-Gazakh zones). In general, *Pinus sylvestris* is more resistant to the continental climate of Azerbaijan than other conifers (e.g. *Picea orientalis*). These results indicate that, *Pinus sylvestris* can be considered a relatively adaptive and resilient species in the context of climate change in the Azerbaijani context.

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TECHNICAL, ECONOMIC AND ECOLOGICAL ANALYSIS OF THE USE OF NATURAL RESOURCES IN THE CONTEXT OF CLIMATE CHANGE

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Abstract

Climate change has further increased the relevance of economic and environmental problems related to the use of natural resources. In this study, a technical, economic and environmental analysis of the use of natural resources was conducted, direct and indirect assessment methods, environmental audit and long-term forecasting approaches were applied. The results show that, the combined application of economic mechanisms with environmental incentives promotes the economical use of resources, reduces waste and strengthens environmental safety. The development of eco-entrepreneurship and eco-management improves both economic indicators and social well-being in the production and service sectors. The study proves that efficient management of natural resources is not only a measure of environmental protection, but also a key condition for sustainable economic development.

Keywords: Climate change, Natural resources, Ecological economics, Sustainable development, Eco-management, Azerbaijan

INTRODUCTION

Climate change has further increased the relevance of economic and ecological problems related to the use of natural resources in modern times. Although the interaction between the development of society and nature is based on balance, anthropogenic impacts disrupt this balance and complicate the efficient use of resources. In this regard, the study of the economic and ecological foundations of nature use is of great scientific and practical importance for ensuring sustainable development.

The modern concept of nature use is not limited only to the extraction and consumption of resources, but is also closely related to their protection, restoration and protection of the interests of future generations. Efficient use, in addition to ensuring economic growth, serves to reduce environmental risks, protect environmental quality and improve social well-being. On the contrary, inefficient use leads to the emergence of ecological crises, increased economic losses and degradation of natural systems *(Goychayli & Ismayilov, 2006).*

The scientific foundations of this field are built on the integration of economics and ecology. The economic approach is concerned with the assessment of resources, the costs and benefits of their use, and the ecological approach is concerned with reducing environmental impacts and protecting natural systems. Thus, the technical, economic and ecological analysis of nature use is complex and requires the application of various methodological approaches.

Historically, starting from classical economic schools, the economic aspects of the relationship between nature and society have been discussed, and since the middle of the 20th century, as a result of the aggravation of environmental problems, "environmental economics" has been formed as a separate scientific field *(Ricardo, D., 1817; Malthus, T.R., 1798; Marx, K., 1867)*. In modern times, the economics of nature use is closely integrated with ecological economics, dealing with resource assessment, the formation of environmental policy, and the development of sustainable development models.

In countries like Azerbaijan, which are rich in natural resources but are vulnerable to the effects of climate change, studying these issues is of particular importance. The aim of the article is to examine the economic and ecological foundations of the use of natural resources against the backdrop of climate change, identify existing problems and provide scientifically based recommendations for their solution.

LİTERATURE REVİEW

Financing of environmental measures and formation of funds have been carried out with different approaches in the experience of different countries. During the USSR, the amount of financial resources allocated for nature protection measures constituted a very small percentage of national income (0.8–1.2% for the whole Union, and 0.3–0.5% in some republics). In modern times, this trend has continued, and budget resources allocated for environmental purposes have been less than 1% of GDP. However, the amount of economic damage resulting from environmental degradation in some countries constitutes 8–15% of GDP, which indicates the inadequacy of financial mechanisms *(Goychayli, Mikayilov, & Abdullayev, 1996).*

In the experience of the Russian Federation, the formation of ecological funds was carried out by dividing them between federal, regional and local budgets, but serious violations were observed in the use of allocated funds. Similar problems existed in Azerbaijan, the rules of ecological funds stipulated in the legislation were not followed, the allocated funds were included in the state budget and redirected to other areas. This situation led to the lack of sustainability in the financing

of ecological programs *(Ministry of Ecology of the Russian Federation, 2019; Ministry of Ecology and Natural Resources of the Republic of Azerbaijan, 2020).*

Financial support from international organizations and donor countries has played an important role in the implementation of environmental measures. National action plans prepared with the assistance of the World Bank and other international funds have been financed through a tender mechanism, but transparency problems have been observed in the use of these resources *(World Bank, 2005; OECD, 2017).*

Environmental insurance and leasing have also been considered as alternative financing mechanisms. Although environmental insurance creates a legal framework for compensating for risks arising from the activities of enterprises, it is accompanied by an additional financial burden. Leasing, on the other hand, is considered a flexible mechanism for long-term financing of environmental protection equipment, but is limited by a high-risk factor.

Overall, the existing literature shows that the effectiveness of environmental funds and alternative financing mechanisms is still limited. The amount of funds allocated is insufficient compared to the scale of environmental problems and is often symbolic in nature. This confirms the existence of institutional gaps in the financing of environmental policy.

MATERIAL AND METHODS

In this study, direct, indirect and modern methods were applied for the economic valuation of natural resources. Direct methods evaluated the rent indicators and production costs formed as a result of the use of resources based on the rent approach, the cost method and the cost-resource approach. Indirect methods were applied in cases where market prices were not available based on the alternative value concept, general economic assessment, subjective approach, transportation costs and real estate prices. Modern approaches included the re-production method and the monopoly-management approach based on payments determined by management bodies to restore the ecological balance *(Daly, H.E., & Farley, J., 2011; Pearce, D., & Turner, R.K., 1990).*

A complex methodological framework has been established for the analysis of ecological and economic processes. At the first stage, a system of ecological and economic indicators and standards was developed based on balance methods, comparative factors and statistical reporting forms. At the next stage, the goals and objectives of ecological and economic analysis were determined, and EIA (Environmental Impact Assessment) and ecological expertise procedures were applied to assess the ecological safety and socio-economic results of projects *(Bayramov, 2011; Jafarova, 2014).*

In addition, an ecological audit was conducted, the stages of selection of objects, collection of initial data, analytical assessment and final reporting were carried out sequentially. Finally, long-term forecasting, balance approaches, extrapolation, expert assessment and modeling methods were used to predict and plan the use of nature. This process was completed by the preparation of ecological passports and the formation of regional programs.

RESULTS

The results of the study showed that, the economic mechanisms of natural resource use and environmental incentives are multifaceted. The analysis proves that, the parallel application of positive and negative economic incentives serves to protect environmental interests in entrepreneurial activity and increase economic efficiency. The introduction of resource and emission payments promotes the economical use of resources, reduces waste and creates a financial source for environmental protection measures.

Analysis of the volume and application mechanisms of pollution charges shows that their real incentive effect is weakened due to insufficient indexation and inflation adjustment. Despite the increase in charges in Azerbaijan and other CIS countries, the weakness of monitoring and accountability mechanisms prevents the full achievement of environmental results. International experience shows that, charges should not only serve the function of collecting funds, but also of stimulating technological modernization.

The results also prove that, the application of eco-entrepreneurship and eco-management creates both economic and social positive effects in the production, service and financial sectors. The development of eco-business ensures the efficient use of resources through waste disposal, reuse of raw materials and energy saving. This not only improves the economic performance of enterprises, but also contributes to environmental protection.

The effectiveness of eco-entrepreneurship manifests itself at different levels:

• At the societal level – reduction of pollution and increase of social welfare;

• At the production level – expansion of use of recycled raw materials and reduction of production costs;

• At the firm level – strengthening of ecological image, achievement of competitive advantage in the market and formation of additional income.

The application of eco-management, along with planning, monitoring and control of environmental safety measures in enterprises, creates conditions for the provision of products and services that meet the requirements of consumers through ecological marketing. This approach increases long-term sustainability and leads to an increase in the ecological and economic effect.

In general, the conducted analyses prove that, the management of nature use is not only an environmental protection measure, but also an important mechanism for increasing economic efficiency.

Analyses of natural resource management show that, efficient use and conservation of resources are key to ecological and economic sustainability. The results show that, conservation and proper management of natural resources not only ensure ecological stability, but also create new opportunities for economic development. According to the observations:

- Resource utilization – efficient use of recycled raw materials and waste reduction reduces production costs and increases productivity.
- Energy savings – economical use of energy resources has a positive impact on the economic performance of enterprises, while also reducing environmental risks.
- Environmental safety – as a result of management measures, environmental pollution is minimized, which leads to an increase in public welfare.
- Socio-economic impacts – as a result of nature use management, the environmental image is strengthened, consumer confidence increases, and a competitive advantage is formed in the market.

Overall, the results show that, nature use management is not only an environmental protection measure, but also an important mechanism for increasing economic efficiency. This approach plays a key role in the implementation of a sustainable development strategy and produces positive results at both the production and societal levels.

CONCLUSION

The results of the study show that, economic mechanisms for the use of natural resources should be aimed not only at financial accumulation, but also at ensuring environmental safety. Proper standardization, indexation and targeting of payments to environmental goals stimulate the efficient use of resources and serve to reduce environmental risks.

In Azerbaijan, it is important to strengthen the legal and regulatory framework in this area, expand the monitoring system and apply international experience. The development of ecological entrepreneurship and eco-management, in addition to improving the economic performance of enterprises, strengthens environmental protection and contributes to the well-being of society.

Thus, efficient management of natural resources acts as one of the main indicators of a sustainable development strategy and plays an important role in ensuring both economic and environmental sustainability.

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CHEMICAL SCIENCES

SYNTHESIS OF RESORCIN-FORMALDEHYDE OLIGOMER IN THE PRESENCE OF A NANOPARTICLE AND OBTAINING SULFOCATIONITE ON ITS BASIS

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Abstract

Thermosetting oligomer-based materials represent one of the important directions in the modern chemical industry. The main advantage of these materials is that during the oligomerization process they undergo irreversible chemical transformations, resulting in materials characterized by high mechanical strength, heat resistance, and chemical stability.

Sulfocationites based on thermosetting oligomers exhibit high thermal and chemical stability, which makes them suitable for use in environments of various chemical nature. In addition, their high ion-exchange capacity plays an important role in applications such as water purification and processes in the oil and gas industry. At the same time, the use of cation-exchange materials in wastewater treatment is of particular importance from the perspective of environmental protection.

The principal function of sulfocationites is the adsorption of cations from different solutions through the ion-exchange mechanism. Owing to this property, sulfonated oligomers are indispensable in processes such as water softening and desalination, gas purification, and the separation of non-ferrous metals from ores in the metallurgical industry.

Thermosetting oligomer-based sulfocationites possess a cross-linked structure, which provides high resistance both to elevated temperatures and to aggressive chemical environments.

The synthesis of sulfocationites generally involves two main stages. First, oligomerization of functional monomers is carried out (typically by the polycondensation method). Subsequently, ionogenic groups are introduced into the structure of the obtained oligomer through an appropriate chemical transformation reaction.

The production of sulfocationites is performed not only on an industrial scale but also in scientific research laboratories. The main goal in synthesizing these materials is to increase their ion-exchange capacity, improve their mechanical and thermal stability, and enhance their selectivity. In recent years, significant progress has been achieved in the development of a new generation of cation-exchange materials based on nanomaterials and hybrid compositions.

In the present study, the main properties of resorcinol–formaldehyde oligomer synthesized in the presence of nanoparticles and the sulfocationite obtained on its basis were investigated.

Keywords: thermosetting, polycondensation, resorcinol–formaldehyde oligomer, silicon dioxide, nanoparticles, sulfonation, sulfocationite

Introduction

In modern materials science, research aimed at obtaining new hybrid systems through the synthesis of functional-group-containing organic and inorganic compounds with nanoparticles is considered an important and relevant scientific direction. Such

systems combine the flexibility, processability, and chemical reactivity of organic compounds with the high mechanical strength, thermal resistance, and chemical stability of inorganic reagents. As a result, materials with distinctive structural and functional properties are obtained [1].

Macromolecular systems based on resorcinol–formaldehyde (RF) are of particular importance. Oligomers formed through the polycondensation reaction of resorcinol and formaldehyde exhibit high chemical and thermal stability and possess the ability to form porous structures. These characteristics make RF-based systems promising for the preparation of sulfocationites, catalyst supports, aerogel structures, and porous carbon materials [2–4].

Among inorganic components, silicon dioxide (SiO_2) nanoparticles play a significant role in the preparation of nanostructured materials due to their high specific surface area, chemical stability, and surface functionalization capability. Their functional groups can effectively interact with oligomer chains, promoting the formation of nanostructured systems. This approach is advantageous for achieving both homogeneous dispersion and structural stability of the resulting materials [5–7].

The functionalization of nanoparticle-containing resorcinol–formaldehyde oligomers through the sulfonation process is of particular importance. The RF oligomer reacts with concentrated sulfuric acid (H_2SO_4), resulting in enrichment with sulfonic groups ($–SO_3H$). During this process, sulfocationites are formed and adsorbed on the material surface. The presence of sulfocationites increases the ion-exchange capacity of the material, helps preserve the porous structure, and enhances its ability to adsorb heavy metal ions [8].

The formation of sulfocationites is not limited only to the introduction of functional groups. At the same time, stable electrostatic interactions are formed between the oligomer network and the particle surface, resulting in homogeneous, porous, and chemically active hybrid materials [9].

Thus, the synthesis of RF oligomers in the presence of SiO_2 nanoparticles followed by sulfonation leading to the formation of sulfocationites has both scientific and practical significance. Studies in this direction enable a deeper understanding of the synthesis mechanism, structural characteristics, and functional properties of such materials. Cation-exchange materials of different grades differ in their main parameters and in the degree of polycondensation. As the degree of polycondensation increases, samples with lower specific volume are obtained, which significantly affects the static and dynamic ion-exchange capacities of the resulting cationites. Therefore, the synthesis of sulfocationites with new compositions and the investigation of their properties, including ion-exchange capacity and chemical stability within different pH ranges, are essential. The preparation of thermosetting oligomer-based sulfocationites and the investigation of their properties are therefore of considerable theoretical and practical relevance. Ion-exchange materials are not simple chemical substances but rather multicomponent systems formed on the basis of high-molecular-weight compounds with different molecular weights. For this reason, it is difficult to determine their exact chemical structure, molecular weight, and some physicochemical parameters. The main characteristics of ion-exchange materials-such as sorption capacity, degree of cross-linking, conductivity, ion-exchange capacity, and swelling degree-are largely determined by the chemical nature of their macromolecular structure. One of the important factors affecting these properties is the pore size of the oligomer framework. Larger pore cells facilitate the penetration of larger ions into the oligomer matrix; however, this may simultaneously reduce the mechanical strength of the material [12–14].

Sulfonation of functionalized oligomers through analogous transformation reactions can also occur in the presence of various functional groups.

Experimental section

In this study, the following chemicals were used: resorcinol ($C_6H_4(OH)_2$), an aqueous 37% solution of formaldehyde, silicon dioxide (SiO_2) nanoparticles, and sulfuric acid (H_2SO_4, 98%). Resorcinol and formaldehyde were employed as the initial reagents for the synthesis of resorcinol–formaldehyde (RF) oligomer. Silicon dioxide nanoparticles were introduced into the system in order to promote the formation of the oligomer structure and to improve its main properties. Sulfuric acid was used for the sulfonation of the material and for the introduction of sulfonic groups into the system. All chemicals were of analytical grade and were used without additional purification. Distilled water was used during the preparation of solutions and throughout the experimental procedures. The resorcinol–formaldehyde oligomer was synthesized by the well-known method based on the non-equilibrium polycondensation reaction of resorcinol and formaldehyde [10–11].

The synthesized nanoparticle-containing resorcinol–formaldehyde oligomer was homogenized, and the resulting mixture was kept in a water bath at a temperature of 50 °C until gel formation occurred. The oligomer obtained by the sol–gel method was subsequently dried. Drying was carried out in a vacuum-type laboratory oven at 105 °C until a constant weight was achieved (Figure 1).

Figure 1. *Resorcinol–formaldehyde oligomer synthesized in the presence of nanoparticles*

To impart ion-exchange properties to the resorcinol–formaldehyde oligomer synthesized in the presence of nanoparticles, the material was subjected to sulfonation with sulfuric acid. For this purpose, a

predetermined amount of the nanoparticle-containing oligomer was placed into a laboratory reactor with a volume of 250 mL equipped with a reflux condenser and a thermometer. Concentrated sulfuric acid (98%) was then added to the reactor, and the mixture was stirred at a temperature of 140 °C while the analogous transformation process was carried out (Figure 2).

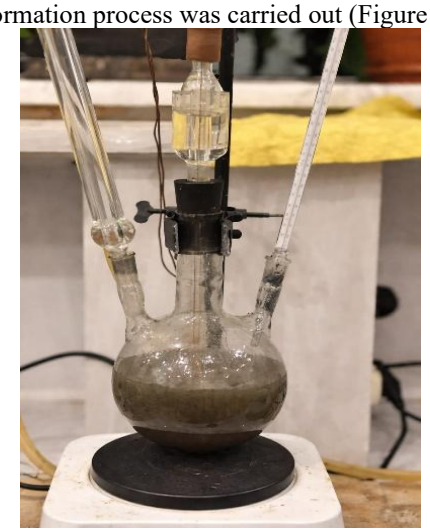

Figure 2. *Synthesis of nanoparticle-containing RF oligomer-based sulfocationite*

After the system became homogeneous, the reaction mass was cooled to room temperature. Subsequently, a 37% aqueous solution of formaldehyde was added to the mixture. The reaction mixture was then placed in an oil bath maintained at a temperature of 110 °C, and the curing process was carried out for 2 hours (Figure 3).

Figure 3. *Nanoparticle-containing RF oligomer-based sulfocationite*

After completion of the reaction, the obtained material was washed with distilled water until the washing water became clear.

The resulting ion-exchange material is a black solid substance, insoluble in water and hydrocarbons, and exhibits sulfocationite properties (Figure 4).

Figure 4. *Prepared sulfocationite*

Subsequently, the product was dried and fractionated into particles with a size range of 1–3 mm. The structure of the sulfocationite was investigated using infrared (IR) spectroscopy [15]. The results of the spectral analysis confirmed the expected structure of the sulfocationite and verified the occurrence of the sulfonation process.

Specifically, the absorption band observed at 3347 cm^{-1} corresponds to the stretching vibrations of –OH groups. The peaks detected in the region of 811 cm^{-1} and 759 cm^{-1} are attributed to deformation vibrations of –CH groups in the aromatic ring, while the bands in the 1500–1450 cm^{-1} region are associated with vibrations of the aromatic benzene ring. Characteristic functional groups of sulfocationites, namely $–SO_3H$ groups, were confirmed by absorption bands in the 1450–1350 cm^{-1} region corresponding to stretching vibrations, as well as bands in the 1100–1070 cm^{-1} region, which are associated with vibrations attributed to nanoparticles (Figure 5).

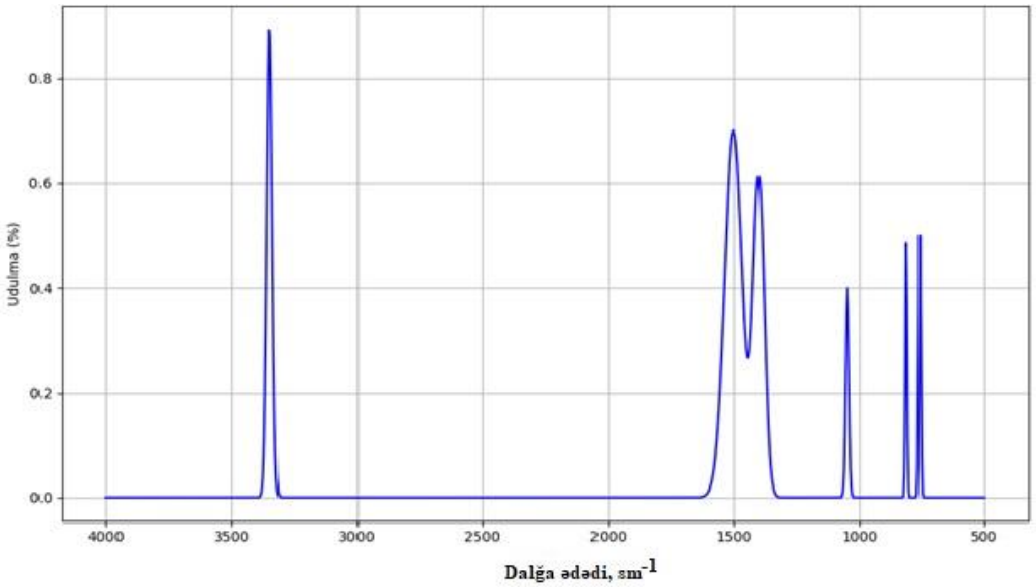

Figure 5. *IR spectrum of the sulfocationite*

The main characteristics of the nanoparticle-containing resorcinol–formaldehyde oligomer-based sulfocationite, as well as a reference resorcinol–formaldehyde oligomer-based sulfocationite prepared for comparative purposes, were investigated.

Main parameters of resorcinol–formaldehyde and nanoparticle-containing resorcinol–formaldehyde oligomer-based sulfocationites

№	Parameters	Sulfocationites	
		RFO-based sulfocationite	Nanoparticle-containing RFO-based sulfocationite
1	Appearance	Dark brown	Black
2	Swelling degree, %	0.22	0.18
3	Specific volume, mL/g	2.84	3.05
4	True density, kg/m³	1081	1120
5	Static ion-exchange capacity, mg eq/g	1.88	2.05
6	Dynamic exchange capacity, mgeq/g	0.74	0.82
7	Particle size	0.7-1.5	0.5-1.2
8	Bulk density, g/mL	0.63	0.58

Conclusion

Both RFO-based and nanoparticle-containing RFO-based sulfocationites are insoluble in any solvents. As a result of the sulfonation of RFO with sulfuric acid, homogeneous, porous, and ion-exchange sulfocationites were obtained. IR spectral analysis confirmed the presence of –OH groups, benzene ring structures, and –SO_3H functional groups. Based on the IR spectra, the existence of these functional groups was verified. The introduction of sulfonic groups enhanced the ion-exchange capacity of the sulfocationites, ensured the preservation of the porous structure, and facilitated stable interactions between the oligomer matrix and the SiO_2 surface. Thus, the prepared sulfocationites are structurally and functionally stable and demonstrate strong potential for metal ion adsorption, catalytic processes, and other environmental applications.

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EVALUATION OF THE CLASSICAL AND MODIFIED GINU FUNCTIONS IN RELATION TO THE ARALKUM DESERT CONDITIONS

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ОЦЕНКА КЛАССИЧЕСКОЙ И МОДИФИЦИРОВАННОЙ ФУНКЦИЙ ЖИНУ ПРИМЕНИТЕЛЬНО К УСЛОВИЯМ ПУСТЫНИ АРАЛКУМ

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Abstract

This article adapts the topographic Ginou function, a dust storm source, to the dynamically changing landscape of the dry Aral Sea bed (Aralkum Desert). The static nature of the original Ginou function does not account for natural and artificial vegetation regeneration processes, leading to errors in dust emission estimates.

The modified Ginou function integrates satellite data based on the NDVI vegetation index, allowing the model to dynamically change the surface erodibility coefficient depending on the seasonal state of the vegetation cover.

The model was tested using dust storm data for all seasons of the year. It was shown that the modified function more accurately reflects seasonal surface conditions, while the classical model overestimates emission volumes, especially during growing seasons. It was found that using the modified Ginou function reduces the estimated environmental load by an average of 9%. An analysis of economic damages using the spring storm of May 27, 2018, originating in the Aralkum Desert as an example showed that using a modified function reduced the estimated loss by USD 2.49 million (9.53%) per square kilometer by taking into account vegetation cover, which prevents dust removal. It was found that the greatest damage (over USD 10 million according to the standard model) occurred in the rural sector, which is critical for the Aral Sea region in the spring.

Using the modified approach prevents excessive insurance provisions and provides more accurate data for assessing the "cost of inaction" when planning phytomelioration measures for the Aral Sea bed.

The proposed approach demonstrates significant effectiveness for regional monitoring of salt and dust transport and can be recommended for refining global climate models in areas of active desertification

Аннотация

В статье выполнена адаптация топографической функции Жину источника пыльных бурь для условий, динамически меняющегося ландшафта высохшего дна Аральского моря (пустыня Аралкум). Статическая природа исходной функции Жину не учитывает процессы естественного и искусственного возобновления растительности, что приводит к погрешностям при оценке эмиссии пыли.

Модифицированная функция Жину интегрирует спутниковые данные на основе индекса вегетации NDVI, что позволяет модели динамически изменять коэффициент эродируемости поверхности в зависимости от сезонного состояния растительного покрова.

Проведена апробация модели на данных о пыльных бурях за все сезоны года. Показано, что модифицированная функция точнее отражает сезонное состояние поверхности, тогда как классическая модель завышает объёмы эмиссии, особенно в периоды вегетации. Установлено, что использование модифицированной функции Жину снижает расчётную экологическую нагрузку в среднем на 9%.

Анализ экономического ущерба на примере весенней бури 27.05.2018 с источником в пустыне Аралкум показал, что использование модифицированной функции позволило снизить оценку потерь на 2,49 млн USD (9,53%) на 1 км² за счёт учёта растительного покрова, препятствующего выносу пыли. Выявлено, что наибольший ущерб (более 10 млн USD по стандартной модели) приходится на сельский сектор, что

критично для Приаралья в весенний период. Применение модифицированного подхода предотвращает избыточное страховое резервирование и даёт более точные данные для оценки «стоимости бездействия» при планировании мероприятий по фитомелиорации дна Аральского моря.

Предложенный подход показывает существенную эффективность для регионального мониторинга соляно-пылевого переноса и может быть рекомендован в целях уточнения глобальных климатических моделей в зонах активного опустынивания.

Key words: Aralkum, Ginu function, NDVI, dust emission, threshold wind speed, economic damage.
Ключевые слова: Аралкум, функция Жину, NDVI, эмиссия пыли, пороговая скорость ветра, экономический ущерб.

Введение.

Взвешенные в воздухе соле-песчаные частицы вследствие пыльной бури играют важную роль в формировании погодных условий, а в долговременной перспективе и климатических условий, в частности, в радиационном балансе Земли [7,14,18]. Кроме того, что чрезвычайно важно, соле-песчаные частицы, как продукт пыльной бури с источником на обсохшем дне Аральского моря (пустыня Аралкум), создают опасные условия качества воздуха, прежде всего, для человека, а также негативно влияющие на растительность, в частности, на сельское хозяйство региона [1,12].

В целях диагноза и прогноза пыльной бури в режиме реального времени, её продукта концентрации взвешенных частиц, их переноса, в настоящее время разработаны ряд численных моделей выбросов и распространение пыли. Эти модели независимо от деталей алгоритма обязательно включают три блока, описывающие процессы эмиссии, переноса и осаждения частиц.

Аналитическая реализация блока эмиссии осуществляется согласно одной из трёх схем, разработанных Б. Мартикореном и Г. Бергаметти [10,11]: блок переноса и дисперсии частиц основан на решении уравнения адвекции и диффузии с учётом метеорологических параметров (ветер, турбулентность); блок осаждения частиц включает такие процедуры, как расчёт гравитационного оседания, вымывание пыли осадками.

Среди численных моделей, наиболее востребованных в работе гидрометеослужб и научных исследованиях, являются мо-дели *WRF-Chem* (*Weather Research and Fo-recasting model coupled with Chemistry*) [6], *DREAM* (*Dust Regional Atmospheric Mo-del*) [3], *GOCART* **(***Goddard Ozone Chemistry Aerosol Radiation and Transport***)** [4]. Для этих моделей одним из входных параметров является активность источника пыли или функция источника пыли (коэффициент эродируемости). Вычисле-ние функции источника пыли *DSF* (*Dust Source Function*) – ключевая процедура в моделировании атмосферных аэрозолей, позволяющая определить источник пылевой бури и его мощность.

Принимая во внимание тот факт, что классическая топографическая функция Жину источника пыльных бурь не учиты-вает активные процессы лесомелиорации пустыни Аралкум, в данной статье рассмотрена модифицированная модель с использованием индекса вегетации *NDVI* для более точной оценки пыльных бурь. Для вычисления функции источника, расположенного на обсохшем дне Аральского моря, за основу взята схема Жину [5], выполнена её модификация с использованием спутниковых данных *AVHRR* и адаптация к условиям обсохшего дна Аральского моря – пустыни Аралкум.

Цель исследования

Разработка и апробации модифицированной методики оценки потенциала пылеобразования в пустыне Аралкум путём интеграции классической функции Жину с динамическими данными индекса вегетации *NDVI*.

Объект исследования

Образовавшаяся вследствие усыхания Аральского моря пустыня Аралкум, рассматриваемая как один из наиболее мощных и вредоносных источников пыльных бурь в Центральной Азии.

Данные и методы расчёта

Построение цифровой модели рельефа области, ограниченной широтами 44-46^{o} с. ш. и долготами 58-61^{o} в. д., выполнялось на основе данных высот превышения над уровнем моря с использованием инструментария пакета *GOOGLE EARTH*. Данные о высотах местности снимались в узлах географи-ческой сетки с шагом 0,1^{o} по долготе и 0,05^{o} по широте (рис. 1). Таким образом была построена матрица высот размером 31×41.

Данные *AVHRR*, доставляемые со спутника *NOAA* выбирались в соответству-ющих диапазонах длин волн для вычисления вегетационного нормализованного индекса *NDVI* по исследуемой территории из банка спутниковых данных о пыльных бурях [2]. Были выбраны даты с пыльными бурями: зима – 28.01.2020; весна –27.05. 2018; лето – 12.06.2020; осень – 04.11.2021. Данные о скорости ветра на соответствующие даты выбраны из банка данных Узгидромета и Казахстанской гидрометеослужбы по метеорологическим станциям, ближайших к пустыне Аралкум (Аральск, Актумсык, Муйнак).

Топографическая функция Жину

Потенциальная эродируемость поверхности, основанная на факте накопления соле-песчаного материала в низинах, описывается функцией Жину, определяющей «геометрическую готовность» участка дна к дефляции:

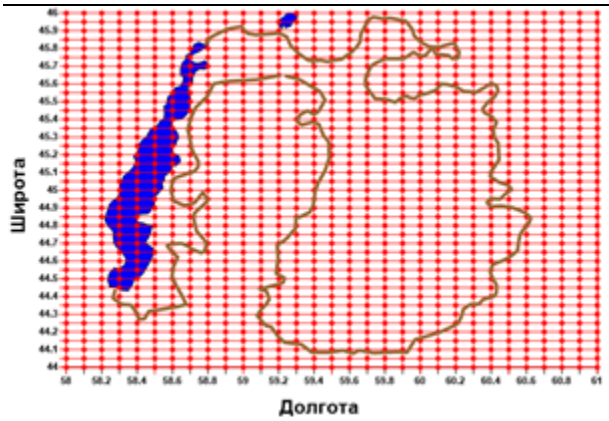

Рис. 1. Географическая сетка, в узлах которой вычислялась функция источника пыли.

Примечание: коричневой линией выделен контур пустыни Аралкум – обсохшее дно Аральского моря.

$$S_i^{Gin} = \left[\frac{Z_{max} - Z_i}{Z_{max} - Z_{min}}\right]^5, \quad 0 \le S^{Gin} \le 1, \quad (1)$$

где Z_{max}, Z_{min} – максимальная и минимальная высоты над уровнем моря в окрестности исследуемой территории.

Функция Жину с учётом NDVI

Для учёта препятствующей развитию пыльной бури роли растительности (саксаул, травянистые сообщества) в (1) вводится коэффициент на основе спутниковых данных [17]:

$$S_i^{st} = \left[\frac{Z_i}{Z_{max}}\right]^5 \times \left[1 - \frac{NDVI_i - NDVI_{min}}{NDVI_{max} - NDVI_{min}}\right] f_i \times f_t,$$

$$0 \le S^{st} \le 1, \quad (2)$$

где $NDVI = \frac{NIR - RED}{NIR + RED}$ (NIR – уровень яркости в инфракрасном канале, RED – в красном канале), множитель $(Z_i/Z_{max})^2$ – геоморфологический фактор, характеризующий накопление эродируемого осадка в низинах; f_i – коэффициент типа землепользования. Для осушённого дна (солончаки/пески) принято f_i =1.0; f_t – текстурный коэффициент почвы. Для рыхлых песков и мелкодисперсных солей Аралкума изменяется в диапазоне 0,6 – 0,9 [15,16]. В расчётах принято среднее значение $\bar{f}_t = 0{,}75$.

Поток эмиссии

Вертикальный поток выноса F_p [г/м^{2}с] солепесчаных частиц с учётом функции Жину S^{Gin} определяется, как, например, в модели GOCART [4], выражением

$$F_p = C \cdot S \cdot u^2_{10} \cdot (u_{10} - u_t), \quad (3)$$

где C=10^{-6} [г·с^2/м^5] в региональных моделях – коэффициент мосштабирования, связывающий поток массы с кинетической энергией ветра и топографическими особенностями местности; u_{10} [м/с] – скорость ветра на высоте 10 м; u_t – пороговая скорость ветра, S – функция Жину – стандартная, либо модифицированная.

Масса вынесенной пыли. Масса M [т/км^2] вынесенной пыли рассчитывается по формуле [4]

$$M = C \cdot A \cdot S \cdot \sum_{i=1}^{t} \left(u_i - u_t\right)^3, \quad (4)$$

где A [км^2] – площадь источника.

Риск дефляции

Риск выноса пыли (дефляции) рассчитывается на основе стандартизованной функции Жину, либо модифицированной с учётом состояния поверхности и внешнего воздействия ветра (динамический фактор) в зависимости от пороговых значений u_t для каждого типа поверхности (рис 2): принято для солончаков u_t = 5-6 м/с, для закреплённых песков – u_t = 9-10 м/с [8].

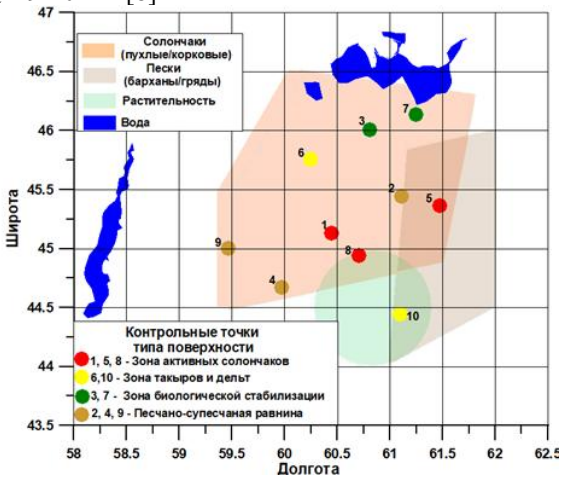

Рис. 2. Карта типов поверхности и очагов дефляции в пустыне Аралкум.

Примечание: числа у кружков – номера точек, в которых выполнялись численные расчёты.

Цифровая модель рельефа

Реализация расчёта функций S_i^{Gin} и S_i^{St} согласно (1), (2) требует наличие дан-ных о превышении высот над уровнем моря – цифровой модели рельефа исследуемой территории, которая была построена для территории, ограниченной широтами 44-46° с. ш. и дол-готами 58-61° в. д. (рис. 3).

Поскольку пространственное разре-шение спутникового снимка AVHRR состав-ляет 1 км, а цифровая модель построена с бо̀льшими шагами по широте и долготе, необходимо привести географические координаты (широту и долготу) к сетке пикселей спутниковых снимков, которые были подвержены первичной обработки – трансформированию в мерка-торскую проекцию и географической привязки (рис. 4).

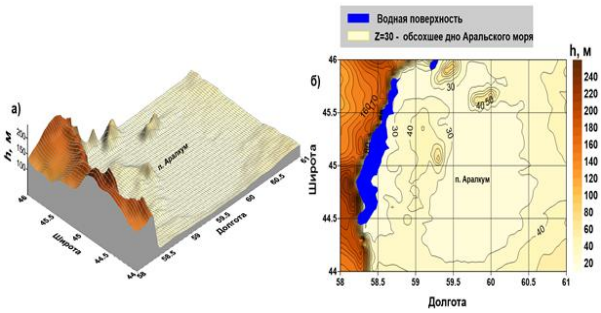

Рис. 3. Цифровая модель рельефа (а) и её контурная проекция (б).

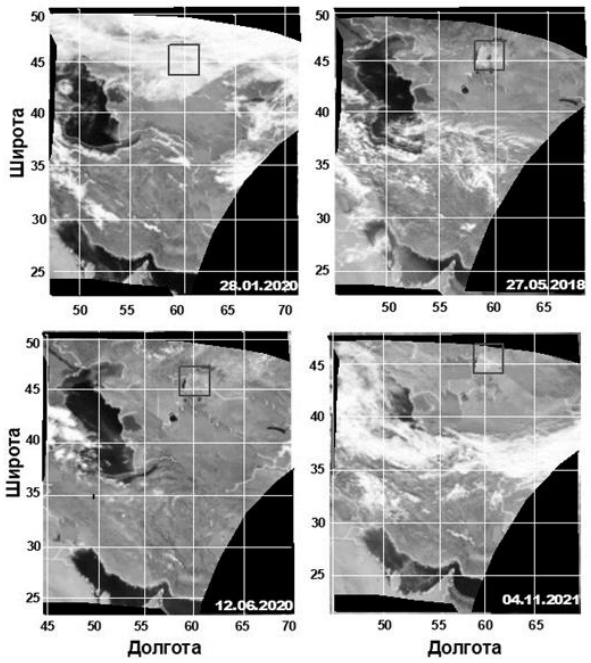

Рис. 4. Трансформированные в меркаторскую проекцию снимки NOAA/AVHRR

Примечание: прямоугольник – выделенная рабочая область.

Указанное выше приведение выпол-нялось методом интерполяция высот превышения из узлов географической сетки в узлы пиксельной сетки с использованием весовой анизотропной интерполяции [9]. Согласно этому методу, значения высот превышения h_o над уровнем моря в интерполированном узле представляется соотношением

$$h_o = \frac{\sum_{v=1}^{m} a_v h_v}{\sum_{v=1}^{m} a_v}, \qquad (5)$$

где h_v – превышение по данным цифровой модели (в узле *v* географической сетки), а веса a_v определяются из решения системы линейных уравнений:

$$\sum_{v=1}^{m} a_k r_{kv} = r_{ov}, \ (k = 1, 2 \ldots m). \qquad (6)$$

В (6) *r* – расстояние, *m* – количество точек, по которым выполняется интерполя-ция в точку «*o*».

Расчёт финансового ущерба от пыльных бурь с источником в пустыни Аралкум выполнялся согласно междунар-родной методике оценки социально-экономических потерь, основанной на удельных затратах на одну тонну пыли [19]. Общий ущерб U_{total} [USD/т] складывается из прямых и косвенных потерь:

$$U_{total} = U_{agr} + U_{infra} + U_{health} + Uenv, \qquad (7)$$

где $U_{agr} = \sum_i (S_i \Delta Y_i \cdot P_i) + C_{reclam}$ – ущерб сельскому хозяйству (S_i площадь поражён-ных земель *i*-го типа, ΔY_i – снижение урожайности на единицу площади, P_i – рыночная цена продукции, C_{reclam} – затраты на промывку почв и внесение удобрений для восстановления плодородия); $U_{infra} = C_{clean} + C_{repair} + L_{trans}$ – ущерб промышленной и социальной инфраструктуре (C_{clean} – затраты на очистку ирригационных каналов, дорог и жилых зон от песка, C_{repair} – дополнительные расходы на ремонт оборудования и зданий, L_{trans} – убытки от простоя транспорта (авиасообщение, автодороги); $U_{health} = \sum_j N_j \times (D_j + M_j + \cdot V_j)$ – ущерб здоровью населе-ния (N_j – количество заболевших *j*-м видом заболевания (респираторные, офтальмологические), D_j– стоимость лечения и медикаментов, M_j– потери ВВП из-за временной нетрудоспособности, V_j – выплаты по социальному страхованию); $Uenv = M \cdot T_{norm} \cdot K_{reg}$ – ущерб экологическим системам (*M* – масса вынесенной пыли, T_{norm} – базовый тариф за тонну загрязняющего вещества, K_{reg} – региональный коэффициент экологической значимости территории).

Численные эксперименты

Численнке эксперименты по расчёту функций S_i^{Gin}, S_i^{St} и F_p выполнялись для дат с пыльными бурями во все сезоны года.

На рис. 5 приведено распределение функций S_i^{Gin} и S_i^{St} по территории пустыни Аралкум в мае месяце. Как следует из рисунка и та и другая функции чётко вылеляют большую область источника пыльных бурь (44-45,5° с.ш. и 59-60,5° в.д.), очервиваемую изолинией 0,9, соответствующей высоте превышения ≈30 м (рис. 3).

Стандартная топографическая функ-ция Жину (1) описывает геоморфологические особенности рельефа: определяет эродируемость поверхности независимо от сезона года на основе топографии. Основная идея заключается в том, что пыль накапливается в топографических понижениях (впадинах), где в результате аллювиальных процессов откладываются мелкодисперсные осадки.

Модифицированная функция (2), включающая член с индексом раститель-ности *NDVI,* учитывает динамику повер-хности в зависимости от сезона

года: сглаживает влияние чистой топографии, перенося акцент на фактическое состояние поверхности, выступает как низкочастот-ный фильтр, сглаживая вклад рельефа в итоговый индекс эрозионной способности в зависимости от сезона года.

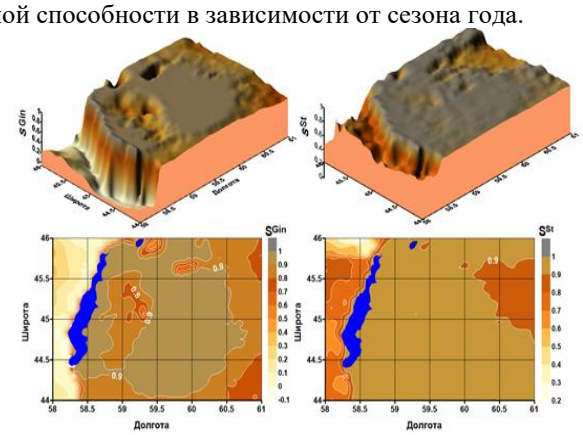

Рис. 5. Распределение функций S^{Gin} (а) и S^{St} (б) в мае. с источником в пустыни Аралкум.

Примечание: внизу – контурные проекции.

Перейдём к анализу количественных различий стандартной и модифицирован-ной функций на примере пыльных бурь в различные сезоны года, а далее рассмотрим сезонные вариации эмиссии пыли на территории источника.

Зимняя пыльная буря 15.01.2021 (рис 4), связана с северо-западным вторжением, вызвана прохождением холодного атмосферного фронта, сопровождавшееся резким усилением ветра до 20–25 м/с.

27 мая 2018 года пыле-солевая буря с источником в пустыне Аралкум (рис. 4) – одно из наиболее масштабных явлений в Узбекистане, как минимум, за последние десятилетия [20], вызванное холодным фронтом северо-западного вторжения, ещё раз показавшее пустыню Аралкум, как одну из наиболее активных источников пыльных бурь в мире [13].

Пыльная буря 12 июня 2020 года (рис. 4) вызвана аномальной летней жарой в Казахстане и Узбекистане (до +46,5 °C), что привело к сильному перегреву поверхности и высокой турбулентности воздуха, сопровождающейся северо-западным и северным направлениями ветра 16-21 м/с и максимальными порывами до 25–28 м/с.

Начавшаяся 4 ноября 2021 года, пыльная буря (рис. 4), вызванная северо-западным вторжением, резким контрастом температур и перепадом атмосферного давления между зоной антициклона и уходящим циклоном создали условия штормового ветра (25-28 м/с, местами до 28 м/с). Эта буря, в своём роде, стала уникальным природным явлением для Узбекистана и юга Казахстана из-за своей интенсивности и продолжительности.

В табл. 1 приведены значения функций S^{Gin}, S^{St}, индекса *NDVI*, вычисленные по контрольным точкам (рис. 2), за указанные выше даты.

Анализ табл. 1 показывает, что в зимней период (январь) *NDVI* минимален, но фактической эрозии препятствует наличие снега и влаги.

Таблица 1

Параметры поверхности и значения функций S^{St} S^{Gin}, полученные в узлах контрольных точек

№	*NDVI*	S^{Gin}	S^{St}	$\Delta = S^{Gin} - S^{St}$	Состояние поверхности в контрольных точках
Зима (15.01.2021)					
1	0.02	0.98	0.99	-0.01	Переувлажнённый солончак
2	0.03	0.97	0.98	-0.01	Снежный покров/иней
3	0.05	0.95	0.96	-0.01	Спящий саксаульник
4	0.02	0.98	0.99	-0.01	Грязевая корка
5	0.01	0.99	1.00	-0.01	Голый клиф
6	0.03	0.97	0.98	-0.01	Русло под снегом
7	0.04	0.96	0.97	-0.01	Мёрзлый песок
8	0.02	0.98	0.99	-0.01	Корка солей
9	0.02	0.98	0.99	-0.01	Островная часть
10	0.04	0.96	0.97	-0.01	Увлажнённая дельта
Среднее	**0.028**	**0.972**	**0.982**	**-0.01**	
Весна (28.05.2018)					
1	0.05	0.95	0.96	-0.01	Почти голая почва
2	0.07	0.93	0.92	0.01	Слабое закрепление
3	0.18	0.82	0.58	0.24	Растительность работает
4	0.06	0.94	0.94	0.00	Стабильно высокая эрозия
5	0.04	0.96	0.97	-0.01	Очаг выноса
6	0.09	0.91	0.85	0.06	Умеренное влияние
7	0.14	0.86	0.72	0.14	Частичная стабилизация
8	0.05	0.95	0.96	-0.01	Солончак активен
9	0.08	0.92	0.88	0.04	Слабое подавление
10	0.11	0.89	0.79	0.10	Весенний рост
Среднее	**0.087**	**0.913**	**0.857**	**0.056**	

Лето (12.06.2020)					
1	0.03	0.97	0.98	-0.01	Максимальная пыль
2	0.04	0.96	0.97	-0.01	Подвижные пески
3	0.09	0.91	0.88	0.03	Вегетация выгорела
4	0.04	0.96	0.97	-0.01	Пересушенная корка
5	0.03	0.97	0.98	-0.01	Активный очаг
6	0.05	0.95	0.96	-0.01	Деградация покрова
7	0.06	0.94	0.94	0.00	Потеря влаги
8	0.03	0.97	0.98	-0.01	Солончак (макс. риск)
9	0.04	0.96	0.97	-0.01	Сухость
10	0.05	0.95	0.96	-0.01	Однородная эрозия
Среднее	**0.046**	**0.954**	**0.959**	**-0.005**	
Осень (4.11.2021)					
1	0.04	0.96	0.97	-0.01	Сухой солончак
2	0.05	0.95	0.96	-0.01	Пески (дефляция)
3	0.12	0.88	0.78	0.1	Частичное восстановление
4	0.05	0.95	0.96	-0.01	Потрескавшаяся глина
5	0.04	0.96	0.97	-0.01	Активный очаг
6	0.07	0.93	0.91	0.02	Уплотнение почвы
7	0.09	0.91	0.86	0.05	Закреплённые участки
8	0.04	0.96	0.97	-0.01	Солевая пыль
9	0.06	0.94	0.93	0.01	Стабилизация
10	0.08	0.92	0.88	0.04	Снижение активности
Среднее	**0.064**	**0.936**	**0.919**	**0.017**	

Стандартная S^{Gin} и модифицирован-ная S^{St} функции Жину в этот период практически одинаковые (разница составляет 1%) из-за отсутствия вегетирующей растительности.

Весной (май) разница между функциями достигает 24% в точках с кустарниковой растительностью (точка №3 на рис. 2). Модифицированная функция S^{St} значительно точнее воспроизводит наличие защитного слоя, игнорируемый функцией S^{Gin}, как если бы, поверхность оставалась бы эродируемой.

В июне обе функции практически совпадают (разрыв 0-1%). Это указывает на то, что в условиях Аралкума летом *NDVI* падает ниже критического порога выжива-емости растений, и любая модификация функции Жину сводится к классическому расчёту для голой почвы.

Осенью растительность частично восстанавливается (поздние эфемеры), а испарение снижается. Поверхность остаёт-ся сухой, но функция S^{St} начинает показывать снижение риска по сравнению с летом (разница составляет 2-5 %).

Сказанное выше можно наглядно видеть на рис. 6, где зимой и летом значения функций, практически одни и те же: зимой из-за отсутствия хлорофилла в растениях (*NDVI*≈0), а летом из-за термического

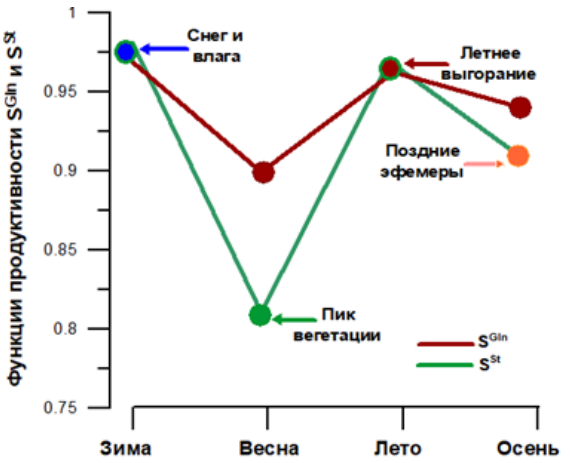

Рис. 6. Сезонная динамика эродируемости пустыни Аралкум.

стресса и высыхания эфемер-ной растительности (летнее выгорание). Весной наблюдается глубокий провал модифицированной функции – период, когда весенняя вегетация максимально защищает почву. Разница между моделями составляет около 10% (в среднем по всем точкам), что критично для точности прогноза пылепереноса. Осенью (ноябрь) наблюдается небольшое снижение S^{St} относительно летнего пика. связанное с сохранением биомассы растениями после летней жары, препятствующая ветру.

В табл. 2 приведена сводная таблица расхождения двух моделей по 10 контроль-ным точкам, где приведены средние значения функций S^{tGin} и S^{St}, их средняя $\overline{\Delta}$ и максимальная разность Δ_{max}.

Таким образом, использование модифицированной функции Жину принципиально важно только для весеннего и осеннего периодов. Для

зимы и лета классическая модель даёт схожий результат, так как значения *NDVI* в условиях Аралкума в эти периоды низкие.

Таблица 2

Среднее расхождение моделей по 10 контрольным точкам

Сезон	$\overline{S^{Gin}}$	$\overline{S^{St}}$	$\overline{\Delta}$	Δ_{max}	Расхождение моделей
Зима	0.972	0.981	0.012	0.015	Модели идентичны
Весна	0.898	0.812	**0.114**	**0.242**	Критическое расхождение
Лето	0.956	0.968	0.014	0.021	Высокая идентичность
Осень	0.935	0.908	**0.045**	**0.108**	Умеренное завышение

Вертикальный поток выноса пыли

Поток эмиссии за все даты пыльных бурь, рассматриваемые в данной статье, были рассчитаны по формуле (3) с использованием классической функции Жину S^{Gin} и модифицированной S^{St}. Пороговые скорости u_t приняты: зима – 7м/с; весна – 8 м/с; лето – 6 м/с; осень – 7 м/с.

Результаты расчётов потока эмиссии приведены в табл. 3 для всех дат сезонов года с пыльными бурями, рассматриваемые в данной статье. Из сравнения таблиц 2 и 3 следует полная согласованность в степени расхождения потока выброса пыли F_p, рассчитанного с использованием функций S^{Gin} и S^{St}, с расхождением значений самих функций. Причины такого расхождения были рассмотрены выше, в частности, наиболее существенную коррекцию модифицированная функция даёт в весенний период. Ещё раз отметим, что применение функции S^{St} для расчёта потока эмиссии делает модель более реальной, по сравнению с моделью S^{Gin}, убирая ложнозавышенные показатели эмиссии.

Таблица 3

Значения потока эмиссии F_p [г/м²с] для четырёх сезонов года

Сезон	Дата	u_{10}, (м/с)	u_t, (м/с)	S^{Gin}	$Fp \cdot 10^{-5}$ (Gin)	S^{St}	$Fp \cdot 10^{-5}$ (St)	Расхождение, %
Зима	15.01.2021	12	7	0,972	**699**	0.981	**706**	+0,93%
Весна	27.05.2018	25	8	0,898	**9541**	0.812	**8627**	**-9,58%**
Лето	12.06.2020	15	6	0,956	**1936**	0.968	**1960**	+1,26%
Осень	04.11.2018	13	7	0,935	**948**	0.908	**921**	**-2,89%**

Масса выноса пыли. Масса M [т/км²] выноса пыли рассчитывалась согласно (4), экстраполированных на 1 км², за даты четырёх сезонов года с использованием стандартной и модифицированной функций Жину. Результаты расчётов выноса массы пыли M^{Gin} и M^{St} представлены в табл. 4.

Как следует из табл. 4, весной функция Жину S^{Gin} переоценивает удельный вынос пыли на 72000 тонн в масштабах пустыни Аралкум. Причиной такой переоценки является то, что S^{Gin} считает поверхность эродируемой уже при $NDVI < 0.15$, в то время как модифицированная функция S^{St} учитывает тот факт, что даже незначительный весенний покров защищает верхний слой почвы. В летний и зимний сезоны разница 1-2% является статистически значимой. Летом, когда растительность выгорает, обе функции реагируют на голую землю одинаково, а зимой та же реакция по причине отсутствия хлорофилла – обе модели одинаково чувствительны к открытому субстрату.

В ноябре стандартная функция завышает вынос на 3.3%. Это указывает на то, что остаточная биомасса (сухие стебли саксаула и солянок) продолжает оказывать механическое сопротивление ветру, которое функция S^{Gin} не способна зафиксировать.

Таким образом, для точного экологического мониторинга пустыни Аралкум весной критически важно использовать модифицированную функцию, чтобы избежать ложных оценок деградации земель.

Таблица 4

Удельный вынос пыли, рассчитанный с использованием стандартной и модифицированной функций Жину

Сезон	Дата	M^{GIN}, т/км²	M^{ST}, т/км²	$\Delta = M^{GIN} - M^{St}$, т/км²	Δ, %
Зима	15.01.2021	342 000	348 000	-6 000	~1.7%
Весна	27.05.2018	**756 000**	**684 000**	**+72 000**	**+10.5%**
Лето	12.06.2020	1 428 000	1 446 000	-18 000	~1.2%
Осень	04.11.2018	552 000	534 000	+18 000	+3.3%

Экономический ущерб. Основной целью оценки экономического ущерба по формулам (7) в контексте данной статьи является расчёт относительного показателя приносимого ущерба пыльными бурями, вычисленного на основе удельной массы пыли, рассчитанной с использованием стандартной и модифицированной функций Жину на примере весенней пыльной бури 27.05.2018.

По данным [19] средний экономический ущерб для региона Приаралья от одной тонны пыле-солевого аэрозоля составляет ≈ 40 USD/т (табл. 5).

Результаты расчёта экономического ущерба на примере весенней пыльной бури

27.05.2018, представленные в табл. 6, показали, что модифицированная функция снижает оценку ущерба на 2,49 млн USD (9,53%) на 1 км^2 за счёт учёта реального состояния поверхности пустыни Аралкум в период вегетации, которое препятствует максимальному выносу пыли.

Таблица 5

Стоимость категорий ущерба для региона Приаралья

Категория ущерба	USD/т	Качественное описание ущерба
Сельское хозяйство	15	Снижение урожайности хлопка и пшеницы из-за засоления
Здравоохранение	12	Рост респираторных заболеваний
Инфраструктура	8	Очистка ирригационных каналов, дорог, износ техники
Экология	5	Деградация пастбищ и гибель дикой флоры
Среднее	**40**	**Удельный ущерб на 1 тонну**

Таблица 6

Финансовый ущерб на 1 км2

Категория ущерба	U, USD/т		$\Delta=U^{Gin}-U^{St}$, USD/т
	U^{Gin}	U^{St}	
Сельское хозяйство	10720080	9699120	1020960
Здравоохранение	8331120	7537680	793440
Инфраструктура	4762800	4309200	453600
Экология	2381400	2154600	226800
Общий ущерб	**26195400**	**23700600**	**2494800**

Из представленных в табл. 5, 6 категорий ущерба, наибольшие потери приходятся на сельский сектор (более 10 млн USD по стандартной модели), что критично для регионов Приаралья в весенний период. Использование модифицированной функции при расчёте экономического ущерба предотвращает избыточное страховое резервирование и даёт более точные данные

для оценки «стоимости бездействия» в вопросах фитомелиорации дна Аральского моря

Выводы

В данном исследовании с использованием *NOAA/AVHRR* изображений было выполнено уточнение функции Жину – функции активности источника пылевых бурь на территории обсохшего дна Аральского моря. Выполненное уточнение на основе введения в модель нормализованного вегетационного индекса *NDVI* показало, что классическая модель Жину завышает объёмы пылевого выноса, особенно в периоды вегетации. Модифицированная функция S^{St} даёт более реалистичную картину для пустыни Аралкум, так как учитывает, что даже скудная растительность создаёт зоны «аэродинамической тени», снижая эффективную площадь дефляции. Модифицированная функция Жину благодаря *NDVI* позволяет учесть долю площади, покрытой растительностью, как функции сезонных изменений состояния почвы.

Использование модифицированной функции снижает расчётную экологичес-кую нагрузку в среднем на 9% по сравнению с классической моделью Жину, предотвращает избыточное страховое резервирование, что критически важно для корректного прогнозирования солепереноса на прилегающие сельскохозяйственные регионы в решении вопросов фитомелиорации дна Аральского моря

Полученные в данной статье результаты указывают на то, что введение в численные модели переноса пыли *WRF/Chem, DREAM* и *GOCART* функции S^{st} вместо используемой по умолчанию функции Жину S^{Gin}, позволит уточнить результаты работы этих моделей.

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ECONOMIC SCIENCES

THE STRAIT OF HORMUZ CRISIS AND GLOBAL OIL PRICE VOLATILITY: ECONOMIC IMPLICATIONS FOR IMPORTING NATIONS

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Abstract
The Strait of Hormuz is one of the most strategically important maritime passages in the world economy. A substantial share of globally traded crude oil and liquefied natural gas passes through this narrow waterway, linking the Persian Gulf to international markets. As a result, any political or military tension in the region has immediate consequences for energy prices, trade expectations, and macroeconomic stability. This article examines how crises in the Strait of Hormuz generate oil price volatility and analyzes the economic consequences for oil-importing nations. It argues that supply uncertainty, transport risk, and speculative reactions in financial markets rapidly transmit regional tensions into global inflationary pressure, slower economic growth, and worsening external balances for importing economies. The study concludes that long-term resilience requires diversification of energy sources, strategic reserves, and structural investment in alternative energy systems.

Keywords: Strait of Hormuz, oil prices, geopolitical risk, inflation, importing nations, energy security

Introduction. Energy security remains one of the defining concerns of the modern global economy. While technological progress and market integration have diversified many supply chains, oil markets continue to depend heavily on a limited number of strategic transport routes. Among these routes, the Strait of Hormuz occupies a uniquely central position. Situated between Iran and Oman, the Strait serves as the maritime gateway for oil exports from Saudi Arabia, Iraq, Kuwait, the United Arab Emirates, and Qatar. Because of its geographic location and narrow navigational lanes, it represents one of the most vulnerable chokepoints in international trade.

Whenever tensions rise in the Persian Gulf, whether through military confrontation, sanctions escalation, attacks on shipping, or threats of closure, oil markets react almost immediately. Prices often increase before any physical disruption occurs, reflecting expectations of scarcity and uncertainty. These reactions matter most for countries that rely heavily on imported energy. For such economies, higher oil prices can weaken industrial output, increase inflation, reduce household purchasing power, and complicate monetary and fiscal policy decisions.

This article explores the relationship between crises in the Strait of Hormuz and global oil price volatility, with particular emphasis on the economic implications for importing nations.

The Strategic Importance of the Strait of Hormuz. The Strait of Hormuz is one of the world's busiest energy corridors. A significant proportion of internationally traded oil and substantial volumes of liquefied natural gas move through this route every day. Its importance is not simply commercial but systemic, since the interruption of flows from the Gulf affects benchmark oil prices worldwide.

Unlike other transport routes, Hormuz has limited short-term substitutes. While some pipelines bypass the Strait, their combined capacity is insufficient to replace maritime flows fully. This means that even a temporary disruption can create strong market reactions. The narrow geography of the Strait increases security sensitivity, as tanker traffic must move through constrained channels vulnerable to military or political pressure.

The economic significance of the Strait therefore extends beyond the Gulf region. It influences production costs, transportation prices, inflation expectations, and investor sentiment across continents.

Crisis Transmission and Oil Price Volatility. Oil prices respond not only to actual supply losses but also to perceived risks. In the case of the Strait of Hormuz, crises tend to affect prices through several interconnected channels.

First, markets immediately reassess the probability of reduced exports from Gulf producers. Even if shipments continue, the possibility of interruption leads traders to price in a risk premium. This premium can become substantial during periods of military escalation.

Second, futures markets amplify expectations. Financial actors often purchase oil contracts in anticipation of higher prices, accelerating upward movement in spot and futures markets simultaneously. Speculative activity does not create the original shock, but it can intensify volatility.

Third, shipping costs rise sharply during crises. Tanker operators may face higher insurance premiums, longer routes, security expenses, and delays. These costs are passed through to importers and ultimately consumers.

Fourth, broader financial uncertainty encourages investors to move toward safe-haven assets such as gold or the US dollar. Currency movements may place additional pressure on emerging economies that import oil in dollar-denominated markets.

Because these channels interact quickly, even short-lived tensions in Hormuz can produce significant global price fluctuations.

Economic Implications for Importing Nations. For oil-importing countries, higher crude prices function as an external shock. Unlike exporting states, importers must absorb rising costs through trade balances, inflation, or reduced growth.

One of the most immediate consequences is inflation. Oil is deeply embedded in transportation, electricity generation, agriculture, and manufacturing. When crude prices rise, fuel and logistics become more expensive, increasing prices across the economy. Food inflation may also accelerate because transport and fertilizer costs often depend on energy prices.

A second consequence is deterioration in the trade balance. Countries that import large quantities of oil must spend more foreign currency to secure the same volume of energy. This widens current account deficits and can reduce foreign exchange reserves, particularly in developing economies.

Third, economic growth may slow. Higher production costs reduce corporate profitability, while households facing expensive fuel and higher consumer prices cut discretionary spending. Investment decisions may also be delayed due to uncertainty. Together, these effects weaken aggregate demand.

Fourth, monetary policy becomes more difficult. Central banks confronting inflationary pressure may raise interest rates, yet tighter policy can further suppress growth. Policymakers therefore face a difficult trade-off between price stability and economic expansion.

Finally, exchange rate volatility often intensifies. Emerging markets dependent on imported energy may experience capital outflows during global shocks. A weaker domestic currency then increases the local cost of oil imports, deepening inflationary pressure.

Policy Responses. To reduce vulnerability, importing nations should diversify energy suppliers, maintain strategic oil reserves, and improve energy efficiency. Long-term investment in renewable energy and alternative technologies can also reduce dependence on imported oil and strengthen economic resilience.

Conclusion. The Strait of Hormuz remains one of the most consequential pressure points in the international economy. Because such a large share of global energy trade passes through this narrow corridor, any crisis in the region rapidly affects oil prices and financial expectations worldwide. For importing nations, the consequences include inflation, weaker growth, deteriorating trade balances, and policy instability.

The continuing relevance of Hormuz demonstrates that globalization has not eliminated geographic vulnerability. Instead, strategic chokepoints still shape economic outcomes across distant markets. Importing nations that wish to reduce future exposure must invest in diversification, efficiency, and long-term energy transition. In an era of recurrent geopolitical tension, resilience is no longer optional but an essential component of economic security.

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THE IMPACT OF EMOTIONAL INTELLIGENCE ON THE BUSINESS PERFORMANCE OF SMALL AND MEDIUM-SIZED ENTERPRISES (SMEs)

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Abstract

This study investigates the impact of emotional intelligence (EI) on the business performance (BP) of small and medium-sized enterprises (SMEs), with a particular focus on the mediating roles of employee engagement (EE) and innovation capability (IC). In the context of increasing market competition and resource constraints faced by SMEs, intangible assets such as emotional intelligence have emerged as critical drivers of organizational effectiveness.

A quantitative research design was employed, and data were collected from 356 managers and employees working in SMEs in Ho Chi Minh City, Vietnam. The study utilizes Partial Least Squares Structural Equation Modeling (PLS-SEM) to test the proposed hypotheses and examine both direct and indirect relationships among the constructs.

The results reveal that emotional intelligence has a significant positive impact on business performance, both directly and indirectly. Specifically, EI positively influences employee engagement and innovation capability, which in turn contribute to improved organizational performance. The mediation analysis indicates that EE and IC partially mediate the relationship between EI and BP, highlighting the importance of internal organizational mechanisms in translating emotional competencies into performance outcomes.

These findings contribute to the existing literature by providing empirical evidence on the strategic role of emotional intelligence in SMEs and by integrating behavioral and innovation perspectives into a unified analytical framework. From a practical standpoint, the study suggests that SMEs should prioritize the development of emotional intelligence through recruitment, training, and leadership development initiatives to enhance competitiveness and long-term sustainability.

Keywords. Emotional intelligence; Business performance; Employee engagement; Innovation capability; SMEs; Structural equation modeling (SEM).

Introduction

In the context of an increasingly volatile and competitive business environment, traditional sources of competitive advantage such as capital, technology, and scale are gradually losing their exclusivity. For small and medium-sized enterprises (SMEs), which often face constraints in financial and technological resources, human capital emerges as a critical determinant of sustainable performance. In this regard, intangible capabilitie particularly emotional intelligence (EI) have gained significant attention as strategic assets that can enhance organizational effectiveness.

Emotional intelligence, broadly defined as the ability to perceive, understand, regulate, and utilize emotions effectively, plays a crucial role in shaping individual behavior and interpersonal dynamics within organizations. Since the foundational works of Peter Salovey and John D. Mayer[1], and later popularized by Daniel Goleman[2], EI has been widely recognized as a key factor influencing leadership effectiveness, job satisfaction, and organizational outcomes. Empirical evidence suggests that individuals with higher EI are better equipped to manage stress, foster collaboration, and make sound decisions under pressure.

Despite the growing body of literature, most prior studies have primarily focused on large organizations or examined EI in isolation, without fully exploring the underlying mechanisms through which EI affects business performance (BP), particularly in SMEs. Moreover, limited research has simultaneously investigated both the direct and indirect effects of EI, especially through critical organizational mediators such as employee engagement (EE) and innovation capability (IC).

Employee engagement reflects the degree of employees' psychological investment in their work, which has been shown to enhance productivity and reduce turnover[3]. Meanwhile, innovation capability enables firms to adapt to market changes, develop new products or services, and maintain competitiveness[4]. Both factors are particularly vital for SMEs operating in dynamic markets where agility and internal cohesion are essential for survival and growth.

Addressing these research gaps, this study aims to empirically examine the impact of emotional intelligence on business performance in SMEs, while simultaneously exploring the mediating roles of employee engagement and innovation capability. Using a structural equation modeling (SEM) approach with data collected from 356 managers and employees, the study provides a comprehensive framework to understand how EI contributes to organizational outcomes both directly and indirectly.

By doing so, this research not only enriches the theoretical understanding of emotional intelligence in organizational contexts but also offers practical implications for SME managers seeking to enhance competitiveness through human resource development strategies.

2. Literature Review

2.1. Emotional Intelligence

Emotional intelligence (EI) has been extensively examined within the fields of organizational behavior and psychology as a multidimensional construct reflecting an individual's capacity to process emotional information and regulate behavior accordingly. The early conceptualization by Peter Salovey and John D. Mayer[1] defines EI as the ability to perceive, assimilate, understand, and manage emotions in oneself and others. This ability enables individuals to navigate social complexities and make informed decisions.

Subsequently, Daniel Goleman[2] expanded the concept into a broader competency-based framework, emphasizing its role in workplace performance, leadership effectiveness, and interpersonal relationships. Goleman argued that EI may be more critical than cognitive intelligence (IQ) in determining professional success, particularly in managerial roles.

Building upon these foundational perspectives, Wong and Law[3] proposed a four-dimensional model of EI tailored for organizational research. This model includes: (1) Self-Emotion Appraisal (SEA), referring to the ability to understand one's own emotions; (2) Others' Emotion Appraisal (OEA), the capacity to perceive others' emotional states; (3) Use of Emotion (UOE), the ability to harness emotions to facilitate performance; and (4) Regulation of Emotion (ROE), the ability to manage emotional responses effectively. This framework has been widely validated and is particularly suitable for empirical studies in business contexts.

In SMEs, where organizational structures are often less formalized and interpersonal interactions are more frequent, EI serves as an internal regulatory mechanism that enhances communication, reduces conflict, and fosters a positive organizational climate. Therefore, EI is expected to play a crucial role in improving both individual and organizational outcomes.

2.2. Emotional Intelligence and Employee Engagement

Employee engagement (EE) is defined as a positive, fulfilling, work-related psychological state characterized by vigor, dedication, and absorption[4]. Engaged employees tend to demonstrate higher levels of motivation, commitment, and discretionary effort, which are essential for organizational success.

Existing literature suggests a strong linkage between EI and EE. Individuals with high emotional intelligence are better able to manage workplace stress, build meaningful relationships, and create a supportive work environment. These factors contribute to increased job satisfaction and stronger emotional attachment to the organization.

Furthermore, leaders with high EI are more likely to exhibit transformational leadership behaviors, such as empathy, emotional support, and effective communication, which significantly enhance employee engagement. As noted by Jordan et al[5], EI can moderate employees' emotional responses to workplace challenges, thereby influencing their level of engagement.

In the context of SMEs, where leadership styles are often personalized and team dynamics are closely interconnected, EI becomes even more critical in fostering engagement. Thus, it is reasonable to expect that EI positively influences employee engagement.

2.3. Emotional Intelligence and Innovation Capability

Innovation capability (IC) refers to an organization's ability to generate, adopt, and implement new ideas, processes, or products to maintain competitiveness. It is widely recognized as a key driver of long-term performance, particularly in dynamic and uncertain business environments.

Emotional intelligence contributes to innovation in several ways. First, individuals with high EI are more open to new experiences and better equipped to cope with uncertainty and risk two essential conditions for innovation. Second, EI enhances collaboration and knowledge sharing among team members, which facilitates the development of creative solutions.

According to Cherniss[6], emotionally intelligent individuals are more adaptable and resilient, enabling them to overcome barriers to innovation such as fear of failure or resistance to change. Moreover, EI supports a psychologically safe work environment where employees feel comfortable expressing novel ideas without fear of criticism.

For SMEs, which often rely on flexibility and rapid innovation to compete with larger firms, fostering EI among employees and managers can significantly enhance innovation capability. Therefore, EI is expected to have a positive impact on IC.

2.4. Employee Engagement, Innovation Capability, and Business Performance

Business performance (BP) encompasses both financial and non-financial outcomes, including profitability, productivity, market share, and customer satisfaction. In contemporary management research, BP is increasingly viewed as a multidimensional construct influenced by both tangible and intangible resources.

Employee engagement has been consistently identified as a key predictor of business performance. Engaged employees are more productive, exhibit lower absenteeism, and contribute to higher customer satisfaction levels[4]. In SMEs, where human resources are limited, the impact of engagement on performance is even more pronounced.

Similarly, innovation capability plays a critical role in enhancing business performance by enabling firms to respond to market changes, differentiate their offerings, and improve operational efficiency. Firms with strong innovation capabilities are more likely to achieve sustainable competitive advantages.

Empirical studies have demonstrated that both EE and IC serve as important mediators linking internal capabilities, such as EI, to organizational outcomes. This suggests that the effect of EI on BP may not be purely direct but also operates through these intermediate variables.

2.5. Emotional Intelligence and Business Performance

The relationship between emotional intelligence and business performance has been widely explored, with most studies indicating a positive association. EI enhances decision-making quality, conflict resolution,

and leadership effectiveness, all of which contribute to improved organizational outcomes.

According to Bar-On[7], EI influences performance through emotional and social competencies that enable individuals to cope effectively with environmental demands. Similarly, Goleman[2] emphasized that organizations with emotionally intelligent leaders tend to outperform their competitors due to better team cohesion and adaptability.

However, the direct impact of EI on BP may be complemented by indirect pathways through organizational processes such as engagement and innovation. Hayes[8] highlights the importance of examining mediation mechanisms to fully understand causal relationships in behavioral research.

Given the limited empirical evidence in the context of SMEs, particularly using advanced analytical techniques such as SEM, this study seeks to fill this gap by proposing and testing a comprehensive model that captures both direct and indirect effects of EI on business performance.

3. Hypotheses Development

Based on the theoretical foundations and prior empirical findings discussed in the Literature Review, this study proposes a research framework examining both the direct and indirect effects of emotional intelligence (EI) on business performance (BP), with employee engagement (EE) and innovation capability (IC) acting as mediating variables.

3.1. Emotional Intelligence and Employee Engagement

Emotional intelligence enables individuals to recognize and regulate their own emotions while understanding those of others, thereby fostering positive interpersonal relationships in the workplace. Employees and managers with high EI are more capable of creating a psychologically safe environment characterized by trust, empathy, and effective communication.

Such an environment significantly enhances employee engagement, as individuals feel valued, supported, and motivated to contribute to organizational goals. Prior research indicates that emotionally intelligent leaders can strengthen employees' emotional attachment to their work and organization, leading to higher levels of engagement and job satisfaction[9].

Accordingly, the following hypothesis is proposed:

H1: Emotional intelligence (EI) has a positive effect on employee engagement (EE).

3.2. Emotional Intelligence and Innovation Capability

Innovation capability reflects an organization's ability to generate and implement new ideas, which is essential for maintaining competitiveness in dynamic markets. Emotional intelligence contributes to this capability by enhancing individuals' adaptability, resilience, and openness to change.

Employees with high EI are more likely to manage uncertainty effectively, overcome fear of failure, and engage in creative problem-solving. Moreover, EI facilitates collaboration and knowledge sharing, both of which are critical for innovation processes. As suggested by prior studies, emotionally intelligent individuals are better equipped to cope with challenges and leverage emotional energy to support innovative thinking[10].

Therefore, the following hypothesis is formulated:

H2: Emotional intelligence (EI) has a positive effect on innovation capability (IC).

3.3. Employee Engagement and Business Performance

Employee engagement has been widely recognized as a key determinant of organizational performance. Engaged employees exhibit higher productivity, stronger commitment, and greater willingness to exert discretionary effort, all of which contribute to improved business outcomes.

In SMEs, where human resources are often limited, the role of engagement becomes even more critical. High levels of engagement can reduce turnover, enhance service quality, and ultimately improve both financial and non-financial performance indicators. Empirical evidence supports the positive relationship between employee engagement and business performance across various organizational contexts[11].

Thus, the following hypothesis is proposed:

H3: Employee engagement (EE) has a positive effect on business performance (BP).

3.4. Innovation Capability and Business Performance

Innovation capability is a fundamental driver of business performance, particularly in competitive and rapidly changing environments. Firms that continuously innovate are better positioned to respond to market demands, develop new products and services, and achieve sustainable growth.

For SMEs, innovation serves as a strategic tool to overcome resource limitations and compete with larger organizations. Studies have shown that firms with strong innovation capabilities tend to achieve higher levels of profitability, market share, and operational efficiency[12].

Accordingly, the following hypothesis is developed:

H4: Innovation capability (IC) has a positive effect on business performance (BP).

3.5. Emotional Intelligence and Business Performance

Emotional intelligence not only influences organizational outcomes indirectly through mediating variables but may also have a direct impact on business performance. Individuals with high EI are better decision-makers, more effective leaders, and more capable of managing workplace conflicts, all of which contribute to improved organizational effectiveness.

Furthermore, EI enhances organizational adaptability and resilience, enabling firms to perform better under pressure and uncertainty. Prior research suggests that emotional competencies play a significant role in driving both individual and organizational performance outcomes[13].

Therefore, the final hypothesis is proposed:

H5: Emotional intelligence (EI) has a positive direct effect on business performance (BP).

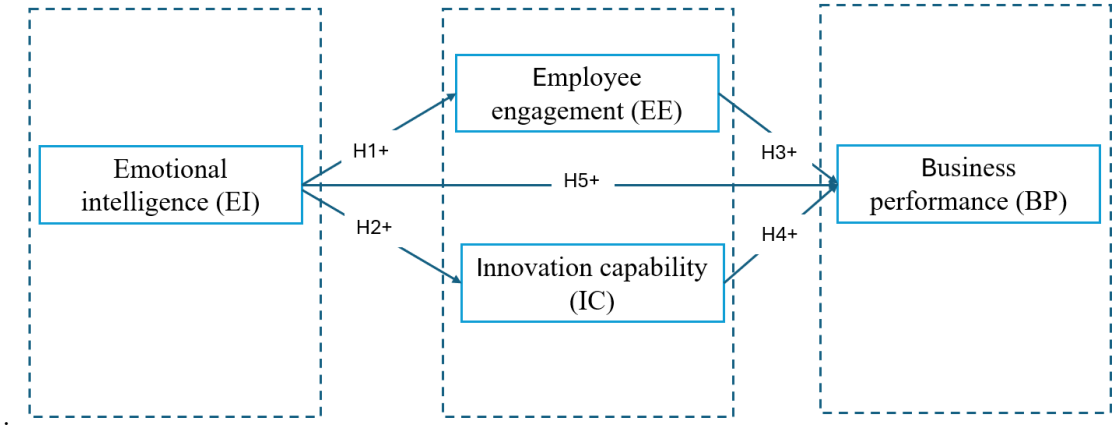

Fig. 1. Conceptual Research Model.

4. Research Methodology

This study adopts a quantitative research approach to rigorously examine the relationships between emotional intelligence (EI), employee engagement (EE), innovation capability (IC), and business performance (BP) within the context of small and medium-sized enterprises (SMEs). Given the complexity of the proposed conceptual framework, which involves multiple latent constructs and mediating mechanisms, a cross-sectional survey design was considered appropriate for capturing empirical data at a single point in time. The research framework is grounded in established theories in organizational behavior and management, and it aims not only to test direct relationships but also to uncover indirect pathways through which EI influences business outcomes. To achieve this objective, Structural Equation Modeling (SEM), specifically the Partial Least Squares approach (PLS-SEM), was employed due to its robustness in handling complex models, relatively small sample sizes, and non-normal data distributions[14].

Data collection was conducted over a three-month period, from January to March 2026, targeting SMEs operating in Ho Chi Minh City, Vietnam. The respondents included middle-level managers and key employees who possess sufficient organizational insight and experience to evaluate both internal processes and performance outcomes. A convenience sampling technique was utilized, which is commonly adopted in exploratory studies where access to respondents is constrained. Although this sampling method may limit generalizability, it is considered acceptable in behavioral and management research when the primary objective is theory testing rather than population inference. The survey instrument was distributed באמצעות an online platform (Google Forms), allowing for efficient data collection while ensuring respondent anonymity and minimizing response bias.

Initially, 380 responses were obtained. However, after a rigorous data screening process including checks for missing values, inconsistent responses, and outliers 356 valid observations were retained for further analysis. This sample size exceeds the minimum requirements suggested by Hair et al.[14] for PLS-SEM analysis, thereby ensuring adequate statistical power and reliability of the results. The demographic profile of respondents indicates a balanced representation in terms of gender, job roles, and work experience, which enhances the credibility of the dataset.

The measurement of constructs in this study is based on well-established scales adapted from prior research to ensure both reliability and validity. Emotional intelligence (EI) was measured using a 16-item scale developed by Wong and Law[3], which captures four core dimensions: self-emotion appraisal, others' emotion appraisal, use of emotion, and regulation of emotion. Employee engagement (EE) was assessed באמצעות a 5-item scale adapted from Schaufeli et al.[4], reflecting key aspects such as vigor, dedication, and absorption. Innovation capability (IC) was measured using 4 items derived from contemporary innovation literature, focusing on the firm's ability to generate and implement new ideas. Business performance (BP), as the dependent variable, was evaluated 5 indicators capturing both financial and non-financial outcomes, including productivity, profitability, and competitive positioning. All measurement items were operationalized using a five-point Likert scale ranging from 1 ("strongly disagree") to 5 ("strongly agree"), following the methodological approach introduced by Likert[15], which is widely accepted in social science research.

The data analysis process was conducted in two main stages using SPSS 26.0 and SmartPLS 4 software. In the first stage, preliminary data analysis was performed to ensure data quality. This included descriptive statistical analysis to summarize respondent characteristics, as well as diagnostic tests to identify potential issues such as missing data and outliers. These steps are critical in ensuring the robustness and validity of subsequent analyses.

In the second stage, the measurement model (outer model) was evaluated to assess the reliability and validity of the constructs. Internal consistency reliability was examined Cronbach's Alpha[16] and

Composite Reliability (CR), with all values exceeding the recommended threshold of 0.7, indicating strong internal consistency. Convergent validity was assessed based on factor loadings and Average Variance Extracted (AVE). All factor loadings were above 0.708, and AVE values exceeded 0.5, satisfying the criteria proposed by Fornell and Larcker[17]. Discriminant validity was further evaluated using the Heterotrait-Monotrait ratio (HTMT), with all values below the threshold of 0.85, confirming that the constructs are empirically distinct from one another[18].

Following the validation of the measurement model, the structural model (inner model) was analyzed to test the proposed hypotheses. Multicollinearity was first assessed the Variance Inflation Factor (VIF), with all values below 3, indicating no significant collinearity issues[14]. The significance of path coefficients was then evaluated a bootstrapping procedure with 5,000 resamples, as recommended by Efron[19], to ensure the robustness of statistical inferences. Additionally, the coefficient of determination (R^2) was used to assess the explanatory power of the model, while effect size (f^2) was calculated to evaluate the contribution of each exogenous construct to the endogenous variables, following the guidelines of Cohen[20].

To further examine the indirect relationships within the model, mediation analysis was conducted based on the approach proposed by Hayes[8]. This analysis enables the identification of whether employee engagement and innovation capability serve as significant mediators in the relationship between emotional intelligence and business performance. The use of this advanced analytical technique enhances the depth of the study by providing insights into the underlying mechanisms driving organizational performance.

Finally, ethical considerations were strictly adhered to throughout the research process. Participants were clearly informed about the purpose of the study, and their participation was entirely voluntary. All responses were collected anonymously, and no personal identifying information was recorded. The data were used solely for academic purposes, ensuring compliance with standard ethical guidelines in social science research.

5. Results

5.1. Sample Characteristics

The analysis is based on 356 valid responses collected from employees and managers working in SMEs. A detailed examination of the sample structure is essential to assess the representativeness and reliability of the dataset. The demographic characteristics of respondents are summarized in Table 1 and visually illustrated in Figure 1.

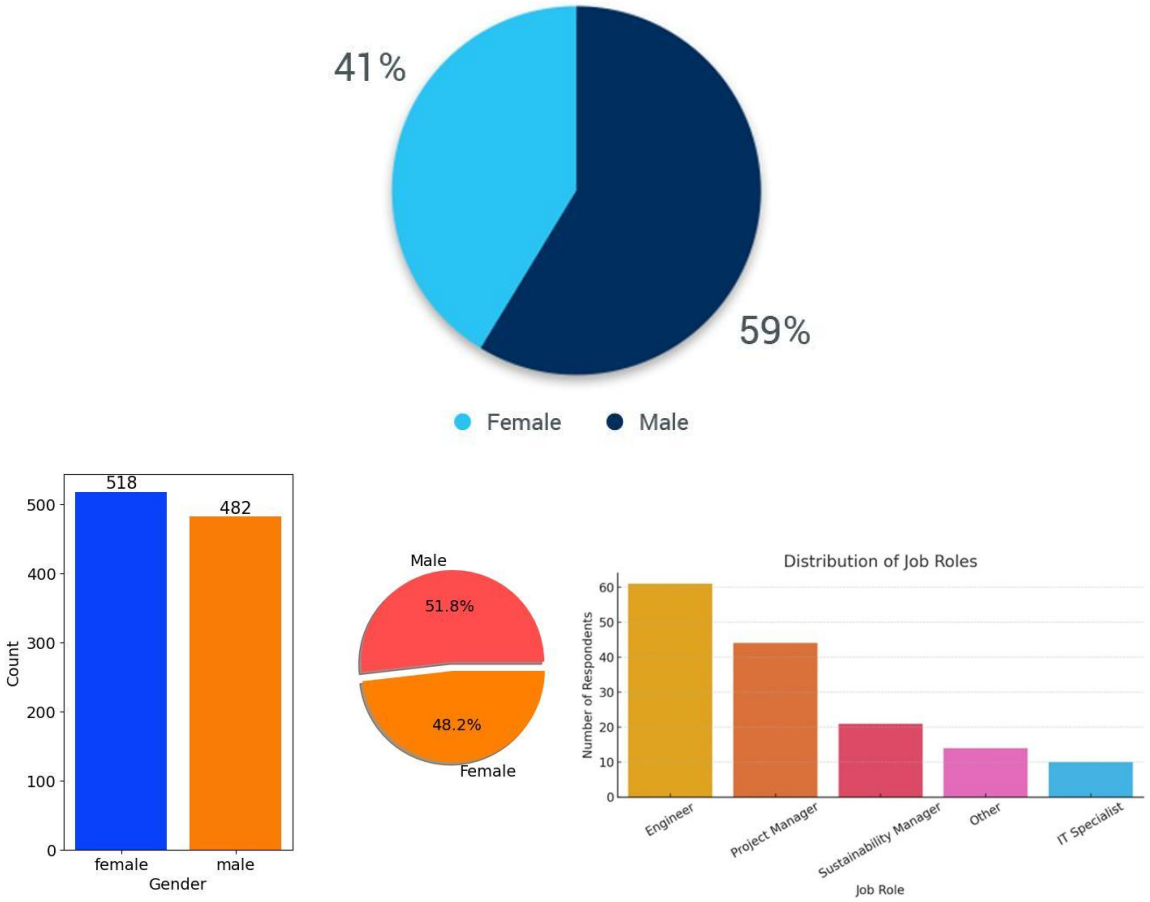

Figure 1. Visualization of Sample Characteristics

The gender distribution indicates a relatively balanced sample, with a slight predominance of male respondents (54.2%). This balance helps minimize gender bias and enhances the generalizability of the findings across different workforce segments.

Regarding organizational roles, the majority of respondents are employees (71.5%), while managers

and business owners account for 28.5%. This composition is appropriate for the study, as employees provide insights into engagement and internal organizational climate, whereas managers contribute strategic perspectives related to innovation and business performance.

Work experience is an important indicator of respondents' ability to provide informed evaluations. The data show that a significant proportion (68.0%) of participants have more than three years of experience, suggesting that they possess sufficient exposure to organizational processes and dynamics. This strengthens the reliability of the responses, as experienced individuals are more likely to accurately assess constructs such as emotional intelligence, engagement, and firm performance.

To provide a clearer understanding of the sample structure, Figure 1 presents a visual representation of the key demographic variables.

Overall, the sample demonstrates adequate diversity in terms of gender, position, and experience, ensuring that the dataset is sufficiently robust for SEM analysis. The relatively high proportion of experienced respondents further enhances the credibility and validity of the empirical findings, as recommended in prior methodological studies[14].

5.2. Measurement Model Assessment

Before testing the structural relationships, the measurement model was evaluated to ensure the reliability and validity of all constructs in accordance with PLS-SEM guidelines.

The results presented in Table 2 indicate that all constructs meet the required thresholds for internal consistency reliability. Specifically, Cronbach's Alpha and Composite Reliability (CR) values exceed 0.7 for all variables, confirming strong internal consistency[16]. Furthermore, all outer loadings are above 0.708, and the Average Variance Extracted (AVE) values range from 0.625 to 0.665, exceeding the minimum threshold of 0.5 recommended by Fornell and Larcker[17]. These findings confirm satisfactory convergent validity.

Table 2.

Reliability and Convergent Validity of Constructs

Constructs	Indicators	Outer Loadings	Cronbach's Alpha	Composite Reliability (CR)	AVE
Emotional Intelligence (EI)	EI1–EI4	0.745–0.852	0.885	0.912	0.625
Employee Engagement (EE)	EE1–EE5	0.780–0.881	0.864	0.901	0.648
Innovation Capability (IC)	IC1–IC4	0.765–0.840	0.832	0.885	0.660
Business Performance (BP)	BP1–BP5	0.755–0.892	0.875	0.908	0.665

To assess discriminant validity, the Heterotrait-Monotrait ratio (HTMT) was employed. All HTMT values fall within the acceptable range (0.415–0.782), which is below the recommended threshold of 0.85[18]. This confirms that the constructs are empirically distinct and measure different conceptual domains.

5.3. Structural Model Assessment

After confirming the adequacy of the measurement model, the structural model was evaluated to test the proposed hypotheses.

First, multicollinearity was examined using the Variance Inflation Factor (VIF). All VIF values range from 1.214 to 1.856, which are well below the threshold of 3, indicating no collinearity issues[14].

Next, the significance of the path coefficients was assessed using bootstrapping with 5,000 resamples[19]. The results, presented in Table 3, show that all hypothesized relationships are statistically significant.

Table 2.

Hypothesis Testing Results (Direct Effects)

Hypothesis	Relationship	Path Coefficient (β)	STDEV	T-value	P-value	Result
H1	EI → EE	0.524	0.045	11.644	0.000	Supported
H2	EI → IC	0.418	0.052	8.038	0.000	Supported
H3	EE → BP	0.315	0.061	5.163	0.000	Supported
H4	IC → BP	0.382	0.055	6.945	0.000	Supported
H5	EI → BP	0.205	0.068	3.014	0.003	Supported

The results indicate that emotional intelligence has a strong positive effect on employee engagement ($\beta = 0.524$, $p < 0.001$) and innovation capability ($\beta = 0.418$, $p < 0.001$), supporting hypotheses H1 and H2. In turn, both employee engagement ($\beta = 0.315$, $p < 0.001$) and innovation capability ($\beta = 0.382$, $p < 0.001$) positively influence business performance, confirming H3 and H4. Additionally, EI also has a direct positive effect on BP ($\beta = 0.205$, $p < 0.01$), supporting H5.

5.4. Mediation Analysis

To further investigate the indirect effects, mediation analysis was conducted following the procedure proposed by Hayes[8]. The results indicate that both employee engagement and innovation capability

act as significant mediators in the relationship between emotional intelligence and business performance.

Specifically, EI has an indirect effect on BP through EE ($\beta = 0.165$, $p < 0.01$) and through IC ($\beta = 0.159$, $p < 0.01$). Since the direct effect of EI on BP remains statistically significant, the mediation is classified as partial mediation. This finding suggests that emotional intelligence influences business performance both directly and indirectly through organizational mechanisms.

5.5. Model Fit and Predictive Power

The explanatory power of the model was assessed using the coefficient of determination (R^2). The results show that the R^2 value for business performance (BP) is 0.542, indicating a moderate to substantial level of explanatory power according to Cohen[20]. This means that approximately 54.2% of the variance in BP is explained by EI, EE, and IC.

Similarly, the R^2 values for employee engagement (0.274) and innovation capability (0.174) indicate moderate explanatory levels, suggesting that while EI plays a significant role, other factors may also influence these constructs.

In terms of effect size (f^2), emotional intelligence demonstrates a strong effect on employee engagement ($f^2 = 0.378$), exceeding the threshold for a large effect as defined by Cohen[20]. This highlights the critical role of EI in fostering employee engagement within SMEs.

6. Discussion

The findings of this study provide strong empirical support for the proposed research model and offer important theoretical and managerial insights into the role of emotional intelligence (EI) in enhancing business performance (BP) within SMEs. By employing a PLS-SEM approach, the study not only confirms the direct impact of EI on organizational outcomes but also uncovers the underlying mechanisms through which EI operates, particularly via employee engagement (EE) and innovation capability (IC).

First, the results demonstrate that emotional intelligence has a significant positive effect on employee engagement (H1: $\beta = 0.524$, $p < 0.001$). This finding is consistent with prior research suggesting that emotionally intelligent individuals are better able to manage interpersonal relationships, create supportive work environments, and foster trust among team members[9]. In SMEs, where organizational structures are often less formalized and communication is more direct, the ability of managers and employees to understand and regulate emotions becomes even more critical. High EI contributes to psychological safety, reduces workplace stress, and enhances employees' sense of belonging, thereby increasing their level of engagement. This result reinforces the argument that EI is a key driver of positive workplace attitudes and behaviors.

Second, the study confirms that emotional intelligence significantly influences innovation capability (H2: $\beta = 0.418$, $p < 0.001$). This finding highlights the role of EI as a facilitator of creativity and adaptability within organizations. Employees with high EI are more resilient in the face of uncertainty and more willing to take calculated risks, both of which are essential for innovation. Moreover, EI enhances collaboration and knowledge sharing, enabling teams to generate and implement new ideas more effectively. This aligns with previous studies indicating that emotional competencies support innovative thinking and organizational learning[10]. In the context of SMEs, where innovation is often a key survival strategy, fostering EI can be a practical approach to strengthening innovation capability.

Third, the results indicate that both employee engagement (H3: $\beta = 0.315$, $p < 0.001$) and innovation capability (H4: $\beta = 0.382$, $p < 0.001$) have significant positive effects on business performance. These findings confirm that engaged employees and innovative practices are critical drivers of organizational success. Employee engagement enhances productivity, reduces turnover, and improves service quality, while innovation capability enables firms to adapt to changing market conditions and maintain competitive advantages. Notably, the effect of innovation capability on business performance is slightly stronger than that of employee engagement, suggesting that innovation may play a more prominent role in driving performance outcomes in SMEs operating in dynamic environments.

Furthermore, the study finds that emotional intelligence has a direct positive impact on business performance (H5: $\beta = 0.205$, $p < 0.01$), even after accounting for mediating variables. This result suggests that EI contributes to organizational effectiveness through multiple pathways. Directly, EI enhances decision-making quality, leadership effectiveness, and conflict resolution, all of which are essential for improving performance. Indirectly, EI influences performance through its effects on engagement and innovation.

The mediation analysis provides additional insights into these indirect mechanisms. Both employee engagement and innovation capability are found to partially mediate the relationship between EI and BP. This indicates that while EI has an independent effect on performance, a substantial portion of its impact is transmitted through organizational processes. Specifically, EI enhances engagement and innovation, which in turn drive business outcomes. This finding is consistent with the mediation framework proposed by Hayes[8] and highlights the importance of examining intermediate variables in organizational research.

From a theoretical perspective, this study contributes to the literature by integrating emotional intelligence with organizational behavior and innovation theories in a single comprehensive model. It extends previous research by demonstrating that EI is not only an individual-level competency but also a strategic organizational resource that influences performance through multiple pathways. The use of SEM further strengthens the validity of the findings by simultaneously testing complex relationships among constructs.

From a practical standpoint, the results suggest that SMEs should place greater emphasis on developing emotional intelligence among their workforce. Unlike traditional resources such as capital

or technology, EI represents a relatively low-cost yet highly effective means of enhancing organizational performance. By investing in EI development, firms can improve employee engagement, foster innovation, and ultimately achieve better business outcomes.

However, the findings should be interpreted with caution. The use of a convenience sampling method may limit the generalizability of the results, and the cross-sectional design does not allow for causal inferences over time. Future research could address these limitations by employing longitudinal designs and more diverse samples across different regions or industries.

In conclusion, this study underscores the central role of emotional intelligence in driving both behavioral and performance outcomes in SMEs. By influencing employee engagement and innovation capability, EI serves as a critical lever for enhancing organizational effectiveness in today's dynamic business environment.

7. Conclusion

This study set out to investigate the impact of emotional intelligence (EI) on business performance (BP) in small and medium-sized enterprises (SMEs), with particular emphasis on the mediating roles of employee engagement (EE) and innovation capability (IC). By employing a Structural Equation Modeling (SEM) approach on data collected from 356 respondents, the research provides robust empirical evidence supporting the proposed conceptual framework.

The findings confirm that emotional intelligence is a critical determinant of organizational success. Specifically, EI was found to have both direct and indirect positive effects on business performance. On the one hand, EI directly enhances performance through improved decision-making, effective communication, and better conflict management. On the other hand, EI indirectly contributes to performance by fostering higher levels of employee engagement and strengthening innovation capability within the organization.

Among the mediating variables, innovation capability exhibited a slightly stronger effect on business performance compared to employee engagement, highlighting the strategic importance of innovation in SMEs operating in competitive and rapidly changing markets. Nevertheless, employee engagement remains a vital factor, as it directly influences productivity, commitment, and organizational stability. The identification of partial mediation effects further suggests that EI operates through multiple pathways, reinforcing its role as both an individual competency and an organizational resource.

From a theoretical perspective, this study contributes to the existing literature by integrating emotional intelligence theory with organizational behavior and innovation frameworks in a unified model. It extends prior research by empirically demonstrating how EI influences business performance not only directly but also through key organizational mechanisms. The application of PLS-SEM provides a comprehensive and rigorous analytical approach, enhancing the validity and reliability of the findings.

From a managerial standpoint, the results offer several important implications for SME leaders. First, organizations should recognize emotional intelligence as a strategic asset rather than merely a personal trait. Incorporating EI into recruitment, training, and leadership development programs can significantly enhance workforce effectiveness. Second, fostering a work environment that promotes psychological safety and emotional awareness can strengthen employee engagement. Third, leveraging EI to encourage openness, collaboration, and risk-taking can enhance innovation capability, thereby improving competitive advantage.

Despite its contributions, the study has certain limitations. The use of convenience sampling may restrict the generalizability of the findings, and the cross-sectional design limits the ability to establish causal relationships over time. Future research could address these limitations by employing longitudinal data, expanding the geographical scope, and incorporating additional variables such as organizational culture or leadership style.

In conclusion, this study highlights the pivotal role of emotional intelligence in driving business performance in SMEs. By influencing both employee engagement and innovation capability, EI emerges as a key lever for enhancing organizational effectiveness and sustaining competitive advantage in an increasingly complex business environment.

8. Managerial Implications

The findings of this study provide several actionable implications for managers and practitioners in small and medium-sized enterprises (SMEs), particularly in leveraging emotional intelligence (EI) as a strategic resource to enhance business performance (BP). Given the resource constraints typically faced by SMEs, the development and effective utilization of human capital especially emotional competencies can serve as a sustainable competitive advantage.

First, organizations should integrate emotional intelligence into their human resource management practices, particularly in recruitment and selection processes. Traditional hiring criteria often prioritize technical skills and cognitive ability (IQ), while overlooking emotional competencies. However, the results of this study suggest that EI plays a crucial role in shaping employee engagement and innovation capability, which ultimately influence business performance. Therefore, firms are encouraged to incorporate standardized EI assessment tools, behavioral interviews, and situational judgment tests to identify candidates with strong emotional awareness, empathy, and self-regulation skills.

Second, SMEs should invest in training and development programs aimed at enhancing employees' emotional intelligence. Unlike fixed traits, EI can be developed through structured interventions such as workshops, coaching sessions, and experiential learning activities. Training programs should focus on key dimensions of EI, including self-awareness, emotional regulation, social skills, and empathy. By

improving these competencies, organizations can foster a more collaborative and resilient workforce capable of handling workplace challenges effectively.

Third, managers should actively cultivate a psychologically safe work environment that encourages open communication and emotional expression. The study highlights that employee engagement (EE) is significantly influenced by emotional intelligence, particularly through the creation of trust and mutual respect. Leaders with high EI are better equipped to understand employees' needs, provide constructive feedback, and resolve conflicts in a supportive manner. Establishing such an environment can enhance employees' sense of belonging and motivation, leading to higher levels of engagement and productivity.

Fourth, organizations should leverage emotional intelligence to stimulate innovation capability (IC). Innovation often involves uncertainty, risk-taking, and the potential for failure, which can create emotional barriers for employees. Managers with high EI can help mitigate these barriers by fostering a culture that tolerates mistakes, encourages experimentation, and values creative contributions. Additionally, emotionally intelligent leaders can facilitate knowledge sharing and collaboration across teams, which are essential for generating and implementing innovative ideas.

Fifth, SMEs should embed emotional intelligence into their leadership development strategies. Leaders play a pivotal role in shaping organizational culture and influencing employee behavior. By developing emotionally intelligent leadership, organizations can enhance decision-making quality, improve team dynamics, and strengthen organizational adaptability. Leadership development programs should therefore emphasize emotional competencies alongside technical and strategic skills.

Finally, from a strategic perspective, SMEs should recognize emotional intelligence as an intangible asset that contributes to long-term performance. Unlike physical or financial resources, EI is difficult for competitors to replicate, making it a valuable source of sustained competitive advantage. By aligning EI development with organizational goals, firms can simultaneously improve employee well-being, innovation outcomes, and overall business performance.

In summary, the managerial implications of this study underscore the importance of shifting from a purely technical management approach to a more human-centered strategy. By systematically developing and leveraging emotional intelligence at both individual and organizational levels, SMEs can enhance engagement, foster innovation, and achieve superior performance outcomes in an increasingly competitive business environment.

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TRANSPARENCY AND FINANCIAL COMMUNICATION AT THE CASABLANCA STOCK EXCHANGE: LISTED AND NON-LISTED MOROCCAN COMPANIES

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Abstract

The transparency of economic and financial information constitutes an essential condition for supporting stakeholders' decision-making processes. However, transparency may also be perceived as a risk to a company's image, particularly when disclosed information is unfavorable. Consequently, corporate attitudes toward transparency remain heterogeneous and extend beyond the mere availability of information to include its reliability and accuracy.

This study proposes a comparative analysis of the level of transparency between listed and non-listed companies, based on a sample of 78 firms listed on the Casablanca Stock Exchange. The findings indicate that listed companies exhibit a higher level of transparency compared

to non-listed firms. Nevertheless, this level remains insufficient to fully meet stakeholders' informational needs. This research contributes to a better understanding of financial commu- nication practices in Morocco and highlights the importance of improving transparency in order to strengthen investor confidence.

Keywords: Transparency; Listed and non-listed companies; Financial and non-financial reporting; Stakeholders; Casablanca; Information disclosure; Casablanca Stock Exchange (CSE).

Introduction

Transparency requirements represent a concrete expression of the informational function of accounting. Enhancing this function constitutes a major objective of accounting practice, as greater transparency is generally associated with higher accounting quality (Gros & Wallek, 2015). In modern financial systems, transparency has become an essential principle for ensuring market efficiency, reducing information asymmetry, and strengthening stakeholder confidence. The increasing globalization of capital markets and the growing informational needs of investors, creditors, and regulators have intensified pressure on firms to provide reliable and comprehensive financial disclosures. Listed companies, due to their economic importance and their dependence on external financing, are subject to stricter disclosure obligations than non-listed firms. In this context, accounting standards such as IFRS play a significant role in improving the comparability, reliability, and transparency of financial reporting. This study therefore examines the role of transparency and financial disclosure practices in listed companies, while highlighting the differences between listed and non-listed firms regarding disclosure requirements and accounting communication.

Literature Review

Transparency practices constitute key mechanisms for establishing investor confidence and improving corporate governance quality. According to Esendemirli and Saygili (2014), transparency and disclosure have become fundamental components of modern governance systems, particularly in international financial markets where investors increasingly rely on financial communication to make investment decisions. The literature distinguishes between different dimensions of transparency. Mancini and Lamboglia (2017) identify formal transparency, qualitative transparency, and overall transparency as major dimensions used to assess the quality of financial disclosure. Transparency is therefore not limited to the quantity of disclosed information but also concerns the accuracy, relevance, and faithful representation of a company's financial situation. Several empirical studies have examined the relationship between accounting standards and transparency. Girbina et al. (2012) demonstrate that the adoption of IFRS positively affects the transparency level of listed companies by increasing disclosure requirements and improving financial reporting practices. Similarly, Albu et al. (2011) show that professional accountants generally perceive IFRS adoption as more relevant for large listed companies than for small non-listed firms, mainly because listed companies face greater informational demands from investors and financial markets. The literature also highlights important differences between listed and non-listed companies regarding disclosure obligations. Listed firms are required to provide continuous and detailed financial communication to ensure market efficiency and investor protection. In contrast, non-listed firms often adopt more limited and selective disclosure practices due to lower regulatory pressure and reduced dependence on external investors

Research Methodology

The objective of this article is to analyze the level of transparency in the financial and non-financial communication of entities listed on the Casablanca Stock Exchange, taking into account the applicable regulatory framework as well as the informational needs of users of such disclosures. The study further examines issues related to the importance and usefulness of promoting transparency and openness policies toward investors, the financial and non-financial reporting practices of

listed and non-listed companies, and the role of auditing in protecting investors' interests.

To achieve this objective, we analyzed and synthesized prior studies and academic contributions published in the specialized literature while considering the relevant regulatory provisions. Our scientific approach is based on a combined qualitative and quantitative methodology aimed at capturing both the theoretical dimensions and practical implications of transparency, particularly in the context of listed companies, while also considering non-listed firms. Given the rapidly evolving nature of this field, press releases and additional publicly available online sources were also incorporated into the analysis.

Through a case study approach, we assess—using a binary logic ("yes" or "no")—the extent to which listed companies comply with transparency requirements and publicly disclose specific information. For the purposes of this research, data were collected directly from the official website of the Casablanca Stock Exchange (https://www.casablanca-bourse.com/fr). Based on these data, analytical categories were developed in order to evaluate the degree of transparency among companies listed on the regulated market of the Casablanca Stock Exchange.

Financial and Non-Financial Reporting of Listed and Non-Listed Companies

Differences in reporting requirements between listed and non-listed companies are natural, as each category operates under distinct economic objectives and informational needs. Consequently, regulatory frameworks must adapt to these specific characteristics. The primary distinction concerns the recipients of financial information, which determines how companies disclose their data. Additional differences are summarized in Table 1 below.

Table 1

Comparison Between Listed and Non-Listed Companies in Terms of Reporting

Elements	**Listed Companies**	**Non-Listed Companies**
Audit	Mandatory statutory audit conducted by independent external auditors	Optional unless legal thresholds are exceeded
Quarterly reporting	Mandatory publication of quarterly results for investors and markets	Not mandatory
Semi-annual reporting	Mandatory publication of certified semi-annual reports	Generally not required
Annual reporting	Mandatory audited annual report publicly available	Mandatory only for shareholders and tax authorities; limited dissemination
Main reporting recipients	Investors, shareholders, regulatory authorities, financial mar- kets, analysts, general public	Owners/shareholders, banks, tax authorities, direct partners
Accounting standards	Mandatory application of IFRS or market-adapted national stan- dards	Generally limited to local/national accounting standards
Level of transparency	Very high: regular and detailed disclosure obligations	More limited: restricted communication
Sanctions for non-compliance	Fines, trading suspension, reputational loss	Local legal sanctions (tax or civil penalties), generally less severe
Reporting objective	Strengthen market confidence, attract investors, ensure share liq- uidity	Compliance with legal obligations and information for owners

For non-listed companies, annual and semi-annual financial statements remain confidential and are submitted exclusively to the Ministry of Public Finance, which publishes only summarized data such as balance sheet totals, key income statement figures, average workforce, and sector of activity.

Table 3 presents the main reporting categories required for listed companies, as specified in AMMC Circular No. 03/19 of February 20, 2019.

Table 2

Reporting Categories for Companies Listed on the Casablanca Stock Exchange

Report Type	Content	Observations
Annual reports	Balance sheet, income statement, management report, audit report	Must be approved by the General Shareholders' Meeting
Semi-annual reports	Balance sheet, income statement, management report	Mandatory for certain companies under AMMC regulations
Quarterly reports	Balance sheet, income statement, management report	Mandatory for companies listed on the regulated market; recommended for others
Current reports	Significant events affecting company activity (general meetings, dividend decisions, capital changes, mergers, litigation, insolvency, etc.)	Published immediately to inform investors and the market

Girbina et al. (2012) demonstrate that the adoption of IFRS has had a positive impact on the transparency level of listed companies, leading to increased disclosure volumes. While these standards enhance transparency in financial reporting, it remains relevant to question whether their application should also be extended to non-listed companies.

Albu et al. (2011) examined professional accountants' perceptions regarding entities that should mandatorily adopt IFRS according to firm size. Their findings indicate that:

- 100% of respondents believe that very large companies (1,000 employees or more) should mandatorily apply IFRS;
- 90% consider that large companies (250–999 employees) should apply them;
- Only 3% believe that all companies in Romania should adopt IFRS.

This latter percentage appears relatively unconvincing. A possible explanation is that small non-listed firms generally lack the primary users—namely investors—for whom complex financial disclosures are intended, and the cost–benefit balance does not provide sufficient incentive for adopting such standards.

The Role of Auditing in Ensuring Transparency

Public-interest entities whose securities are traded on a regulated market are legally required to have their annual financial statements, prepared in accordance with IFRS, audited. Financial auditing demonstrates its importance for listed companies due to the demand for this activity, which arises from the existence of a conflict of interest between the company, responsible for the disclosed information, and the users of that information. Audited information is more credible and useful for key users' decision-making processes, particularly investors.

Auditing plays a vital role in the proper functioning of capital markets by promoting transparency and protecting investors' interests. Essentially, financial auditing ensures transparency, i.e., the credibility of the financial statements' content. As noted by Lander Auger (2008): "The audit committee must be accountable at a higher level for the types of transactions used by the company and ensure that the substance of economic reality is transparently communicated to investors."

Auditing financial statements also serves to reduce information risk, thereby decreasing the risk premium required by investors and, consequently, lowering the cost of capital (Danescu, 2007).

The auditor is responsible, beyond mere professional service, for the public interest regarding all parties using the audited information in their decision-making process. To serve this public interest, auditors must adhere to fundamental principles applicable to all accounting professionals: integrity, objectivity, professional competence, confidentiality, professional behavior, and compliance with technical and professional standards. These principles enable auditors to perform their work to the highest standards and provide an independent opinion that is reliable for both direct and indirect beneficiaries.

An unqualified audit opinion enhances a company's image with shareholders and potential investors, as it provides reasonable assurance that the financial statements are free from material fraud or error and that the company is trustworthy. The assurances provided by audit professionals constitute the best "business card" to gain investor confidence. The utility of an unqualified opinion is underscored by its inverse forms: qualified opinion, adverse opinion, or disclaimer of opinion. Without these distinctions, unqualified opinions would become a common denominator across companies, forcing investors to rely on other criteria for decision-making.

In this context, a 2015 study by Cordos Fulop notes that, following the Enron scandal, auditors became more cautious and stringent, with qualified opinions increasingly reflecting reality, helping auditors regain investor trust. The study also reports increased stakeholder confidence in Big Four auditors compared with smaller audit firms. For listed companies on the Casablanca Stock Exchange, those audited by reputable firms generally receive unqualified opinions, reflecting rigor and reliability. Companies audited by smaller firms may receive qualified opinions, indicating aspects to monitor in their financial statements.

Case Study on the Communication of Listed Companies via Their Websites

In the digital era, an online presence via a website is fundamental for any company. It is the simplest way for an investor or potential investor to engage with the company. Therefore, it is crucial that all publicly relevant information be presented in a structured, easily accessible, and readable format: company presentation, latest news, financial and other regular reports, shareholder meeting information, etc. Developing a dedicated Investor Relations (IR) section in French and English increases the likelihood that investors will familiarize themselves with the issuer and make informed investment decisions.

To evaluate and enhance transparency and communication between listed companies and investors, the Casablanca Stock Exchange conducted a study on the information provided by listed companies via their websites. Aspects such as the presence or absence of an IR section in French and English, indication of stock listing, stock price information, and a dedicated corporate governance section were identified.

Table 3

Criteria Met by Listed Companies

Number of Criteria	Number of Companies	Percentage
0-1	4	5.13%
2	1	1.28%
5	1	1.28%
6	38	48.72%
8	9	11.54%
9	25	32.05%
Total	78	100%

In Figure 1, it can be observed that the majority of listed companies comply with six criteria (48.72%), while 25 companies (32.05%) meet nine criteria. The extremes—0–1 criterion and 2 or 5 criteria—are observed in fewer companies, accounting for 5.13% and 1.28%, respectively. This results in an average of approximately six criteria being met by the analyzed companies. Variations exist in the information disclosed by the entities; even within the same company, certain areas exhibit higher levels of transparency than others.

While the degree of transparency among companies listed on the regulated market of the Casablanca Stock Exchange (CSE), considered as a reference, ranges from medium to high, questions remain regarding the communication practices of companies listed in other categories. In this context, it is unsurprising that some resource holders remain hesitant to invest in the capital market.

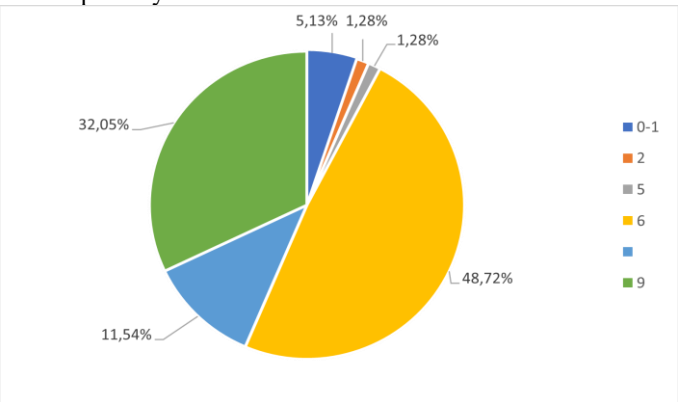

Figure 1: Graphical representation of the number of criteria met by listed companies

A vertical analysis of the information available on company websites indicates that 97.44% of companies have published an Investor Relations (IR) section in French, while 34.62% also provide investor information in English. Furthermore, 92.31% indicate their listing on the official site, and 84.62% provide stock price information. An IR section on corporate governance is available for 51.28% of the companies.

Additionally, 94.87% of companies make their financial reports available, 52.56% have an audit committee, 85.90% disclose their ownership structure, and 92.31% provide contact information. These results show that, despite the widespread availability of basic information and financial reports, some essential information—such as communication in English or the existence of an audit committee—remains less common, potentially limiting access to information for certain investors and stakeholders.

Given that transparency objectives are not fully achieved with satisfactory coverage, the Casablanca Stock Exchange (CSE) has announced the launch of a new reporting system for companies listed on the regulated market, called the Issuer Reporting Information System (SIRE). This initiative by the CSE to standardize reporting via the SIRE platform is commendable, as the strengths and weaknesses identified by CSE specialists reveal some inconsistencies in reporting practices and, consequently, a lack of comparability.

According to the CSE press release, SIRE provides issuers with a mechanism compliant with the

highest international standards, enabling rapid and efficient public dissemination of reports and information to investors. The platform aims to standardize reporting formats to ensure comparability and enhance market transparency, offering a secure and reliable communication system for publishing and distributing issuer reports. By launching the SIRE platform, the CSE provides a dedicated information channel allowing listed companies to communicate with the market in a rapid, transparent, and reliable manner.

An analysis of the websites of certain non-listed companies shows that financial and non-financial information intended for investors, which could also interest other categories of users, is entirely absent. This is understandable, as their objective is not to raise funds through the capital market. Some of these companies are start-ups or remain family-owned businesses, even though their turnover, employee numbers, and total assets over recent years place them among large entities.

Conclusion

Given the role of listed companies in the Moroccan economic market, considering the stakeholders involved—primarily investors—and their information needs, the complex, transparent, and continuous communication required of listed companies, as compared to non-listed firms, is fully justified. Listed companies should not hide behind the concept of confidential information to withhold important and relevant data; instead, they must demonstrate transparency and fairness in their relations with investors.

However, in practice, the transparency of listed companies often remains limited to legally mandated reporting obligations, and sometimes in a superficial manner. Our study highlights numerous gaps in both the form and content of reports. The Casablanca Stock Exchange (CSE) should implement clear and accessible procedures for all interested stakeholders to improve information dissemination. In this regard, the CSE's initiative to create the SIRE platform to standardize reporting represents a significant step toward a more functional and transparent capital market.

Furthermore, companies should develop their own policies for communicating non-financial information beyond legal requirements, even though discretion—also referred to as confidentiality—remains a natural and prudent stance for accountants regarding financial and non-financial data. Transparency and communication remain fundamental principles of an effective capital market.

Corporate governance also plays a complementary role. Implementing good practices, such as holding regular meetings with financial analysts, brokers, and other market specialists, allows companies to present relevant financial analyses to support investor decision-making, since statutory auditing ensures the credibility of financial statements but does not interpret the numbers.

This research contributes to the theoretical development and improvement of economic practices in Morocco and provides a starting point for further investigation into transparency issues. It is recommended to continue monitoring the measures implemented by listed companies to inform investors and to analyze transparency aspects in greater detail—both in terms of form and content—in order to strengthen trust and enhance the efficiency of the Moroccan capital market.

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JURISPRUDENCE

GEODETIC SUPPORT FOR THE DOCUMENTATION AND PRESERVATION OF IMMOVABLE CULTURAL HERITAGE IN BULGARIA: INTEGRATING THE CONCEPT OF "METRIC MEMORY" INTO NATIONAL STRATEGY

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Abstract
The documentation of immovable cultural heritage is undergoing a paradigm shift from traditional 2D drafting to high-dimensional spatial data acquisition. This paper explores the critical role of geodetic support in the documentation and preservation (conservation, restoration, and presentation) of immovable cultural heritage. Central to this discussion is the concept of "Metric Memory"—the precise digital preservation of an object's geometry as its digital DNA. Using the Bulgarian legislative and technical framework as a case study, the paper compares national practices with European standards and proposes a strategic framework (Aims, Objectives, Measures, and Activities) to modernize heritage documentation through the implementation of Heritage Building Information Modeling and standardized geodetic protocols.

Keywords: Metric Memory, Geomatics, Immovable Cultural Heritage, HBIM, ICOMOS, Restoration, Bulgaria.

1. Introduction

Immovable Cultural Heritage (ICH) represents a non-renewable resource, continuously threatened by environmental factors, anthropogenic activities, and natural disasters. Geodesy, as the classical foundation, and its contemporary systemic paradigm — Geomatics (the modern ecosystem) — provide the fundamental metric basis for all efforts concerning the documentation and preservation of ICH sites. Transcending conventional surveying, modern Geomatics — encompassing Terrestrial Laser Scanning (TLS), Unmanned Aircraft Systems (UAS) photogrammetry, and Global Navigation Satellite Systems (GNSS) — serves as a pivotal instrument for the creation of "Metric Memory".

2. The Concept of "Metric Memory" in Heritage Science

The concept of "Metric Memory" is pivotal in the contemporary theory of documentation and preservation of ICH sites. It represents the synthesis of all precise spatial data describing an object at a specific point in time. Within this context, spatial data encompasses: coordinates and elevations within the legally established reference coordinate and vertical systems; dimensions — such as length, width, and height; as well as geometries, volumes, and other correlative spatial attributes.

2.1. Defining Metric Memory

If an ICH site carries historical memory (events) and artistic memory (aesthetics), then "Metric Memory" constitutes its physical DNA. It represents a "freezing" of the object's geometry through acquired and modeled geodetic data, derived from direct measurements and/or existing analogue or digital records. This encompasses not only idealized forms (e.g., the structural height of a wall) but also all inherent deformations — inclinations, distortions, stone erosion, and structural fissures.

"Metric Memory" ensures that a site is "remembered" with absolute precision, even in the event of its physical destruction.

2.2. Components

"Metric Memory" is constructed through several informational layers:

- Geometric Precision: The exact spatial and temporal coordinates of every point on the surface of the ICH site.
- Textural Authenticity: The photorealistic representation of materials, including color, patina, and tool marks.
- Chronological Layers: Documentation of geometric transformations across different historical epochs.

2.3. Role in the Documentation and Preservation of ICH

Metric Memory serves three primary objectives:

- Evidentiary Base: It provides irrefutable evidence of the monument's state prior to intervention, preventing "over-restoration" that might compromise its authentic character.
- Comparative Analysis: It enables multi-temporal surveys (e.g., after 10 or 50 years) where software-based overlays identify millimetric inclinations or the exact extent of relief erosion.
- Virtual Accessibility: It facilitates digital archives and VR experiences, ensuring access even when a site is closed for restoration.

2.4. Geodesy as the Architect of "Metric Memory"

The geodesist acts as the "librarian" of this memory. Utilizing tools such as laser scanners and photogrammetry, they translate physical matter into digital code. While a standard photograph provides visual memory (how it looks), a geodetic survey provides metric memory — defining exactly how large it is and where every particle is situated in space and time.

2.6. Systematic Benefits

The systematic benefits can be summarized as follows:

- For Science: An objective data source for architectural and structural analysis.
- For the State: Legal certainty regarding the boundaries and volume of the cultural asset.
- For the Future: A guarantee for post-disaster restoration (as seen with Notre Dame, where pre-existing metric memory was invaluable).
- Axiology of Measurement: In the spirit of the Venice Charter (1964), restoration must stop where guesswork begins. Metric memory provides the empirical boundary for this principle.
- Digital Twins: High-density point clouds (>1000 points/m²) act as digital twins, capturing structural pathologies invisible to the naked eye.

Metric Memory transcends visual representation. It is the synthesis of spatial coordinates, texture, and structural integrity.

3. Legal and Regulatory Framework in Bulgaria

Bulgaria possesses a rich heritage but faces a complex regulatory landscape. The documentation process is governed by:

- The Cultural Heritage Act [2]: Mandates the identification and documentation of monuments.
- Ordinance No. N-12 (2012) [3]: Specifies the requirements for the "National Register of Immovable Cultural Properties".
- Ordinance No. 1 (2011) [4]: Regulates geodetic requirements for archaeological excavations.

Despite this, there is a lack of a unified technical standard for 3D documentation quality, often leading to inconsistent data formats between the National Institute of Immovable Cultural Heritage (NIICH) and the Geodesy, Cartography and Cadastre Agency (GCCA) [5, 13].

4. Comparative Analysis: Bulgaria vs. Global Standards

While Bulgarian experts utilize state-of-the-art hardware (e.g., Leica, Trimble and Riegl), the systemic integration of these technologies differs significantly from the methodologies adopted by leading nations (Italy / Germany / UK):

Feature	Bulgaria	Italy / Germany / UK
Data Format	Primarily 2D CAD	3D HBIM / OpenBIM
Standardization	Project-specific	National Standards (e.g., PAS 1192-3)
Cloud Infrastructure	Fragmented	National Geospatial Portals (Open Data)
HBIM Maturity	Pilot / Academic stage	Mandatory for public tenders

5. Strategic Framework for National Implementation

The strategic framework presented herein integrates a scientific approach with the practical requirements for geodetic support in Bulgaria.

5.1. Aim 1: Establishing a Unified National Ecosystem for the "Metric Memory" of ICH

This goal is directed toward the strategic preservation of heritage information in a digital format.

- Objectives:
  - Achieve 100% digitization of Bulgarian sites of national and global significance (UNESCO) through 3D methodologies by 2030.
  - Ensure full interoperability between the datasets of the Ministry of Culture (NIICH) and the Geodesy, Cartography and Cadastre Agency (GCCA).
- Measures:
  - Establishment of a National GIS Platform for Immovable Cultural Heritage (ICH).
  - Development of a unified technical standard for the geodetic surveying of ICH sites.
- Activities:
  - Execution of large-scale Terrestrial Laser Scanning (TLS) and aerial photogrammetry on priority sites.
  - Hosting of high-density point clouds on state-owned server infrastructure.
  - Implementation of georeferencing procedures for ICH sites within the legally established Bulgarian Geodetic System 2005 (BGS 2005) [6].

5.2. Aim 2: Modernizing the Engineering Approach in Conservation and Restoration

This goal focuses on utilizing Geomatics as a precision technical tool for direct intervention on heritage sites.

- Objectives:
  - Implementation of HBIM (Heritage Building Information Modeling) as a mandatory design standard for restoration projects.
  - Mitigation of structural collapse risks for endangered monuments through early-warning monitoring systems.
- Measures:
  - Technological upgrading of the methodology for preparing investment projects within the "Geodetic" functional scope.
  - Establishment of a permanent geodetic monitoring program for threatened heritage sites.
- Activities:
  - Generation of 3D information models for sites undergoing restoration.
  - Installation of automated deformation monitoring systems (prisms, tilt sensors) on sites with structural pathologies.

- Production of high-detail orthophoto plan (orthophoto) of facades specifically for restoration requirements.

5.3. Aim 3: Enhancing Institutional and Expert Capacity

This goal addresses the human factor and the regulatory framework essential for the realization of the aforementioned objectives.

- Objectives:
- Establishment of a specialized corps of certified geodesists specifically licensed to work on cultural heritage sites.
- Harmonization of Bulgarian legislation with international guidelines set by ICOMOS [7, 8] and CIPA Heritage Documentation [9-12].
- Measures:
- Regulatory reform of the Cultural Heritage Act [2] and its associated secondary legislation.
- Educational integration between the engineering and humanities disciplines.
- Activities:
- Organization of certified postgraduate qualification courses at the University of Architecture, Civil Engineering and Geodesy (UACEG), Sofia, on the topic of "Geodesy and Cultural Heritage.
- Updating the requirements within Ordinance No. N-12 (2012) [3] regarding the specifications for graphic documentation.
- Conducting inter-institutional training for NIICH inspectors on the utilization of digital control and monitoring instruments.

6. Key Performance Indicators

Key Performance Indicators (KPIs) transform abstract goals into measurable outcomes. They are essential for demonstrating that the proposed approach is both controllable and realistic.

Below are specific indicators categorized by the Aim 1, Aim 2 and Aim 3:

6.1. Aim 1: National Ecosystem for "Metric Memory"

Specific Objective	KPI	Target Value
Digitization of Sites	Percentage of surveyed sites within the "World" and "National Significance" categories.	100% by 2030
Metric Accuracy	Root Mean Square Error (RMSE) in surveying architectural details.	1 sigma < 5 mm
Data Volume	Number of stored Point Clouds in the centralized archive.	> 1,000 datasets
Interoperability	Number of shared GIS layers between NIICH and GCCA.	100% automated exchange

6.2. Aim 2: Modernizing the Engineering Approach (Restoration)

Specific Objective	KPI	Target Value
HBIM Implementation	Share of restoration projects developed via 3D Information Modeling.	70% of public tenders
Early Monitoring	Response time upon detection of critical deformation via sensors.	< 60 minutes (auto-alert)
Design Efficiency	Reduction in execution errors caused by inaccurate baseline data.	-30% vs. current levels
Digital Availability	Number of sites with available 3D tactile models or VR interpretations.	50 key sites

6.3. Aim 3: Institutional and Expert Capacity

Specific Objective	KPI	Target Value
Staff Certification	Number of licensed geodesists specialized in "Cultural Heritage."	Min. 100 persons nationwide
Regulatory Reform	Number of updated ordinances and instructions in the "Culture" sector.	3 key regulatory acts
Training	Annual hours of postgraduate qualification for state employees.	40 hours per employee/year
Project Quality	Percentage of geodetic surveys returned for revision by NIICH.	< 10% of total submissions

6.4. Reporting Methodology

The KPIs presented above are scientifically rigorous and based on the SMART criteria (Specific, Measurable, Achievable, Relevant, Time-bound).

A quarterly monitoring of activities and an annual audit of achieved goals are proposed. Utilizing these KPIs will allow state institutions to transition from reactive management (response) to proactive management (loss prevention through precision data). In scientific terms, this demonstrates how applied geomatics methods translate into tangible economic and social benefits for society.

7. Conclusion

Geodetic support is not merely a technical prerequisite but the "guardian of authenticity" in cultural heritage. By evolving from 2D documentation to a standardized, HBIM-integrated Metric Memory, Bulgaria can ensure that its immovable heritage is preserved not only in stone but in an immutable digital archive. The

synergy between the Venice Charter's ethics and Geomatics' precision is the only way to safeguard our past for a digital future.

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AN ACTION FOR ACKNOWLEDGEMENT AS AN EFFECTIVE CIVIL PROCEDURAL REMEDY FOR THE RESTORATION OF RIGHTS

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Abstract

The present article provides an overview of the action for acknowledgement and its relationship with civil procedural remedies for the effective restoration of rights.

The restoration of disputed or violated rights of individuals falls within the competence of the courts. Clear and foreseeable procedural institutions further enhance the practical realization of the right to a fair trial. An action for acknowledgement constitutes an effective procedural instrument for applying to the court, the proper use of which may lead to outcomes that cannot be achieved through other legal means. Accordingly, the relevance of studying the action for acknowledgement and the necessity of defining its legal nature are evident.

The paper analyzes the types of action for acknowledgement. It also examines the necessity of defining the subject matter of the lawsuit with precision and the exclusion of abstract legal issues from the scope of judicial review. At the same time, particular attention is given to the subsidiary nature of the declaratory lawsuit.

The study reflects the challenges existing in Georgian legal practice and doctrine. It analyzes the case law of the Supreme Court of Georgia, as well as the judicial practice of Germany and other European countries. A significant part of the research is devoted to the concept of legal interest as a primary prerequisite for the admissibility of an action for acknowledgement, along with its defining criteria based on case law and legal doctrine.

The paper is based on a comparative analysis of Georgian, German, and Austrian law. The article evaluates the action for acknowledgement as an effective procedural mechanism that contributes both to the protection of individual rights and to the efficient functioning of the civil justice system.

The research employs several methods: the method of analysis and synthesis, the method of logical analysis, and the comparative legal method.

Keywords: Civil procedure, Action for acknowledgement, Legal interest, Subsidiary nature.

- Introduction

Civil procedure law encompasses the body of rules governing the organization and functioning of the system of justice.[1] Civil procedure determines the procedural mechanisms for the protection of rights granted to legal subjects by substantive law.[2] The principle of party disposition, adversarial proceedings, and judicial discretion collectively form the regulatory framework for the administration of civil justice.[3] "In any case, procedural legislation must be reduced to two fundamental objectives: first, how to ensure the independence of the judiciary so that proceedings are conducted on the basis of adversariality and party disposition; and second, how to simplify the procedure for the adjudication of civil disputes in order to ensure the effective protection of the rights of legal subjects."[4] The cornerstone of judicial proceedings is the effective restoration of violated or disputed rights. Civil procedural legislation serves multiple purposes,[5] among which the regulation of the rules and procedures governing the adjudication of cases by the courts is particularly noteworthy. At the same time, civil proceedings contribute to the expression of the abstract values of society.[6]

In the constitutions of legal and democratic states, provisions can be found granting every individual the right to apply to a court for the protection of their rights.[7] This right is also guaranteed by various supranational, binding international instruments, such as the European Convention on Human Rights, the Charter of Fundamental Rights of the European Union, and the American Convention on Human Rights..[8]

In order to ensure the equal protection of the rights of every individual, it is necessary to establish clear and

[1] Labadie, D, La procédure civile, Pages 33 à 43, 05/12/2019
[2] Clermont, K, Civil Procedure, Black letter outlines, Thomson/West, 8th ed, 2009, 1.
[3] Kiriiak, O, Method of civil procedure, International Comparative Jurisprudence Volume 1, Issue 2, December 2015, 143.
[4] Khurtsilava. R., Simplified Procedure in the Civil Procedure of Georgia, Dissertation, 2009, Tbilisi, 14.
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[7] Constitution Of Georgia, Consolidated publications: 29/06/2020, Article 31.1.
[8] Bado, K, Galič, V, Mendes, A, Huber, S, and others, Procedural Rights, Principles, and Approaches Influencing the Structure of Civil Litigation, Comparative Procedural Law and Justice (Part VI Chapter 1), 13.

foreseeable procedural institutions. It is one thing when national legislation strictly regulates the procedures for the adjudication of civil cases by courts, and quite another when the procedural means of access to the court are transparent and clearly defined. According to the principle of party disposition, the initiation of civil proceedings is based on the filing of a lawsuit or application with the court.[9] "The court may refuse to accept an application or to examine a case only on the grounds and in accordance with the procedure established by the Civil Procedure Code.""[10] It is not surprising that both the procedural codes of individual countries and legal doctrine reinforce the rule of classifying a lawsuit from a civil procedural point of view.[11]

The plaintiff, depending on their legal interest, the subject matter of the dispute, and the nature of the lawsuit, selects a specific type of action. The definitions of claims for alteration of legal relations and "Transforming Lawsuits" are relatively straightforward. However, with regard to the action for acknowledgement, difficulties of interpretation arise both in legal literature and in judicial practice. For example, in Austria, after prolonged debates, the action for acknowledgement eventually established its place within the legal system.[12]

The principal characteristic of a declaratory lawsuit lies in its preventive nature, meaning that it aims to protect a person's legal position before their right is directly violated. Such a type of lawsuit indeed constitutes an effective means of restoring rights, as evidenced by the fact that an action for acknowledgement is inadmissible where a lawsuit for performance can be brought.

Although such a provision is not explicitly found in the Georgian Civil Procedure Code, it is, similarly to Germany, firmly established through judicial practice. Therefore, for a person seeking the resolution of a legal dispute, where the prerequisites for filing a declaratory lawsuit are present, an action for acknowledgement represents the ultimate procedural remedy. At the same time, an action for acknowledgement is distinguished by one specific element, legal interest, which is characteristic exclusively of this type of lawsuit.

Accordingly, the relevance of studying the action for acknowledgement is evident for determining its role in the administration of civil justice.

- Types, subject matter, and subsidiary nature of the action for acknowledgement

An action for acknowledgement is a purely procedural institution and, accordingly, a distinct form of legal protection.[13] This type of lawsuit is defined by Article 180 of the Civil Procedure Code of Georgia.[14], The latter mirrors the provision of § 256 of the German Code of Civil Procedure. The purpose of actions for acknowledgement is to eliminate legal uncertainty regarding a right, rather than to seek the attribution of a subjective right.[15] The distinctive nature of a declaratory lawsuit in relation to other types of lawsuits becomes evident from the very moment of its definition. An action for acknowledgement does not aim to impose the performance of a specific act, but is directed solely toward the clarification and determination of a legal relationship.[16]

It is difficult to find explicit provisions in the civil procedural legislation of any country concerning the types of an action for acknowledgement. This is not surprising, as the law defines only the normative concept of the procedural institution, while practice, driven by necessity, ensures its classification into specific forms. An example of this is the action for acknowledgement, which, according to legal doctrine, may be divided into positive and negative forms.

A positive action for acknowledgement arises where a person requests the court to establish the existence of a specific right or legal relationship, as well as to confirm the authenticity of a document. For example, an action for the establishment of paternity or for the recognition of the right to use property constitutes a positive action for acknowledgement.[17]

In the case of a negative declaratory lawsuit, a person requests the court to establish the non-existence of a right or legal relationship, such as the invalidity of a specific transaction. A negative action for acknowledgement also encompasses claims concerning the falsity of a document. Accordingly, it is evident that the assessment of a document's authenticity falls within the scope of an action for acknowledgement. In many

[9] Culda, S, The Principle Of Party Disposition In Civil Lawsuits, Fiat Iustitia No. 2/2018, 46-47, Available at: https://fiatiustitia.ro/wp-content/uploads/2021/03/376-Article-Text-730-1-10-20190404.pdf [08/04/2026]

[10] Khurtsilava. R., Simplified Procedure in the Civil Procedure of Georgia, 2009, Tbilisi, Publishing house: "Meridiani", 19.

[11] Georgian procedural legislation, similar to that of European countries, recognizes three types of lawsuits: claims for alteration of legal relation, Transforming Lawsuits, and actions for acknowledgement. The purpose of each of them in the administration of justice is the same; however, the distinguishing factor lies in their legal nature. Reference: Liluashvili T., Liluashvili G., Khrustali V., Dzlierishvili Z., Civil Procedural Law, Part II, Tbilisi, 2023, p. 23.

[12] Trzaskalik, Die Rechtsschutzzone der Feststellungsklage im Zivil- und Verwaltungsprozeß: Studien zur Fortentwicklung des Rechtsschutzverständnisses (1978) 12

[13] Rechberger/Klicka in Rechberger/Klicka, ZPO5 § 228 Rz 1. Cited in: Wilfinger, A, Grundfragen der Feststellungsklage, 2025, Monografie, Verlag Österreich, 19.

[14] Civil Procedure Code of Georgia, consolidated version - 09/12/2025 , available at: https://matsne.gov.ge/document/view/29962?publication=174 [08/04/2026]

[15] Kurdadze Sh., Adjudication of Civil Cases in the Court of First Instance, Tbilisi, 2016, p. 479.

[16] Klausurtypische Probleme der Feststellungsklage, Übersicht Feststellungsklagen / Seite 1, available at:https://www.assessorkurs-hemmer.de/pdf/kursmaterialpdf/bayern/1615-uebersichtfeststellungsklage.pdf [08/04/2026]

[17] Liluashvili T., Liluashvili G., Khrustali V., Dzlierishvili Z., Civil Procedural Law, Part II, Tbilisi, 2023, p. 31.

instances, "a negative action for acknowledgement and the decision rendered thereon do not determine what is to be protected, but rather indicate what must be avoided." [18]

The subject matter of a declaratory lawsuit may consist solely of a specific right or legal relationship. A vague or non-specific claim cannot become the object of adjudication in an action for acknowledgement. On the other hand, it is equally undisputed that abstract legal issues are excluded from serving as the subject matter of such a type of lawsuit..[19] This position is also reflected in German judicial practice, which clearly states that "abstract legal issues cannot be resolved by a decision rendered in a declaratory action."[20] The subject matter of an action for acknowledgement may even include legal relationships that have expired, provided that they continue to serve as a basis for ongoing claims. [21]

A distinctive feature of an action for acknowledgement is its subsidiary nature. The court will declare such an action inadmissible if it is possible to bring an action for performance or a constitutive action. Based on the analysis of an interpretation by the German Federal Court, it may be concluded that the subsidiary nature of an action for acknowledgement promotes the rational use of procedural costs and the proper implementation of procedural economy.[22] "In another case, the Federal Court held that an action for acknowledgement must fully correspond to the plaintiff's legitimate legal interest and should not require the plaintiff to reapply to the court in order to protect the same right.".[23] A similar approach is reflected in Article 228 of the Austrian Civil Procedure Code, while legal doctrine indicates that there is no legal interest in an action for acknowledgement if an action for performance or a constitutive action can provide everything that is sought through a declaratory action.[24] In this regard, according to the well-established practice of the Supreme Court of Georgia, based on the principle of procedural economy, "a person must achieve the restoration of a violated right and the improvement of their legal position through the filing of a single lawsuit rather than multiple actions. In other words, the satisfaction of an action for acknowledgement must produce a beneficial result for the plaintiff and eliminate the need to bring an action for performance."[25]

- Prerequisites for bringing an action for acknowledgement and legal interest

Courts are not competent to provide general opinions on legal situations, as, according to established practice, even interesting legal issues must be resolved outside the courtroom "by going to the legal library." [26]

In Austrian law, abstract legal issues, hypothetical situations, individual elements of legal relationships, facts (with the exception of the authenticity or non-authenticity of documents), and certain legal characterizations of facts are not subject to determination by state courts.[27]

"The existence of a legal interest in an action for acknowledgement constitutes an essential prerequisite for its admissibility".[28] "This specific form of legal protection is available only to those who possess a particular interest in obtaining a legally binding decision that can be achieved exclusively through this means."

"In the case of instituting an action for acknowledgement, the legal interest indicated by the plaintiff must be genuine and valid, that is, capable of being achieved. The plaintiff's desire is one thing, while the genuine legal interest underlying the action is another; these two must not be equated. The concept of legal interest always implies the substantive right whose protection is ensured through an action for acknowledgement." [29]

Georgian judicial practice establishes the criteria for determining the legal interest in an action for acknowledgement, namely: (a) the plaintiff's right must be disputed; (b) the existence of the dispute must create a real risk of future violation of the plaintiff's right; and (c) the resolution of the action for acknowledgement must constitute the most appropriate means of resolving the dispute. Furthermore, in order to determine the existence of a legal interest, it must primarily be assessed whether the plaintiff's legal

[18] Das erkennt auch Loyal, ZZP 130 (2017), S.203, 206. Cited in: Placke, E, Nichtige Urteile als Gegenstand einer Feststellungsklage im Sinne des § 256 ZPO, Dissertation, des Fachbereichs der Rechtswissenschaften der Universität Osnabrück, Osnabrück, 2023, 60.

[19] Frauenberger-Pfeiler in Fasching/Konecny, ZPG3 § 228 ZPO Rz 65 Cited in: Wilfinger, A, Grundfragen der Feststellungsklage, 2025, Monografie, Verlag Österreich, 3.

[20] RGZ 148, 81 , 100; BGH WM 2001, 378 , 380; BAG NJW 1985, 220.

[21] BGH NJW 1958, 1293 ; BGH WM 1981, 1050 ; BAG NJW 1994, 1751

[22] BGH Urt. v. 22.7. 2021 - VII ZR 113/20, MDR 2021, 1410.

[23] BGH NJW 1997, 870; BGH NJW 2003, 3274

[24] Frauenberger-Pfeiler in Fasching/Konecny, ZPG3 § 228 ZPO Rz 110 f; vgl im vorliegenden Kontext bereits Hellwig, Anspruch 412. Cited in: Wilfinger, A, Grundfragen der Feststellungsklage, 2025, Monografie, Verlag Österreich, 15.

[25] Supreme Court of Georgia, Chamber of Civil Cases, Case №ას-1389-2018, 30.11.2018

[26] Dobbs/Roberts, Remedies3 7. Cited in: Wilfinger, A, Grundfragen der Feststellungsklage, 2025, Monografie, Verlag Österreich, 3.

[27] Frauenberger/Pfeiler in Fasching/Konecny III/I3 § 228 ZPO Rz 37 ff; ausführlich Jacobs, Gegenstand des Feststellungsverfahrens36 ff; siehe auch die schweizerischen Autoren Dietrich, Zulassung der Feststellungsklagen 90 f und Chern, Die Feststellungsklage im Feststellungsprozeß (1997) 107 ff. Cited in: Alice, A, Die Feststellungsklage im Schiedsverfahren, Exposé zur Dissertation, Wien, Dezember 2018, 6.

[28] RIS-Justiz RS0039177, Cited in: Wilfinger, A, Grundfragen der Feststellungsklage, 2025, Monografie, Verlag Österreich, 5.

[29] Supreme Court of Georgia, Chamber of Civil Cases, Case № 55-54-2014, 21.07.2014

position will improve upon the satisfaction of the declaratory lawsuit.[30]

In one case, the Court of Cassation noted that "the recognition of paternity, the establishment of paternity, the annulment of marriage, the recognition of authorship of a literary work, and similar actions are not aimed at the attribution of a subjective right, but rather at eliminating the uncertainty surrounding a right. In such cases, it is not necessary for the right to have already been violated; rather, the assumption that it may be violated in the future constitutes the plaintiff's legal interest."[31]

Civil proceedings are conducted on the basis of the adversarial principle. The court is not authorized to interfere with the parties' autonomy or to engage in qualified argumentation on their behalf. However, the court is, of course, obliged to regulate procedural matters: it must not assume the role of a subject of substantive law, yet it must also prevent the parties from disregarding the fundamental principles of procedural law. This position is also reflected in the practice of the Supreme Court of Georgia, which notes that "although the cassation complaint does not contain an objection concerning the absence of a legal interest in the claim, the existence of a legal interest in an action for acknowledgement is a procedural issue that the court must examine even in the absence of any indication by the parties, in order to avoid futile proceedings incapable of producing a meaningful legal outcome."[32]

Legal interest constitutes the primary threshold for bringing an action for acknowledgement, and its proper articulation often presents difficulties for plaintiffs. In legal discourse, legal interest is frequently associated with an already materialized outcome; however, the assumption that a right may be violated in the future also constitutes a legal interest. Nevertheless, not every assumption can serve as a sufficient basis for the admissibility of an action for acknowledgement. In one case, the German Federal Court disagreed with the lower courts and held that the legal interest in a declaratory action may arise from the inevitability of future damage. The factual circumstances of the case revealed that, out of 35 elements of a fence exterior repaired by the contractor, 24 had already been damaged. The plaintiff (the client) filed an action for acknowledgement with respect to the remaining 11 elements, supported by an expert report confirming the likelihood of further damage. The plaintiff sought a determination of the obligation to compensate for damage that would arise in the future. The Federal Court clarified that the plaintiff was not required to wait for the damage to actually occur. A legal interest in the immediate determination of the existence or non-existence of a legal relationship always exists where the plaintiff's right is under threat.[33]

- Conclusion

An action for acknowledgement constitutes one of the significant and distinctive institutions of civil procedural law, ensuring the clarification and protection of a person's legal position even in cases where the right has not yet been directly violated, but there exists a real risk of its violation.

The research has demonstrated that the specific nature of a declaratory action is determined by several key elements: its subsidiary character, the necessity of legal interest, and the clear determination of its subject matter. The cumulative presence of each of these elements is mandatory for the admissibility of an action for acknowledgement. Subsidiarity indicates that this type of action is employed only when other procedural remedies (actions for performance or constitutive actions) are incapable of effectively safeguarding the plaintiff's interests.

Particular attention is given to the existence of a legal interest, which constitutes the primary criterion for the admissibility of an action for acknowledgement. Legal interest must be real, specific, and directed toward the improvement of the plaintiff's legal position. A purely hypothetical or abstract assumption is not sufficient. It is necessary that there be a dispute or a real risk of a violation of a right, the elimination of which can be achieved through a judicial decision.

Both Georgian, as well as German and Austrian legal doctrine and judicial practice, unanimously indicate that an action for acknowledgement plays a significant role from the perspective of the principle of procedural economy. It enables a person to avoid more severe legal consequences and to establish their legal position in a timely manner.

Accordingly, an action for acknowledgement constitutes an effective civil procedural remedy for the restoration of rights. Its good-faith and highly qualified application ensures both the protection of individual rights and the efficient and rational functioning of the civil justice system.

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10. BGH NJW 1958, 1293; BGH WM 1981, 1050; BAG NJW 1994, 1751.

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MATHEMATICAL SCIENCES

ADVECTION AND FILAMENTATION OF A PASSIVE SCALAR ON TOROIDAL STREAM SURFACES

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Abstract

We investigate the three-dimensional advection and filamentation of a localized passive scalar on toroidal stream surfaces, motivated by the internal structure of the Hill vortex [4, 8]. Using a geometrically consistent model [10] in which particle motion is constrained to invariant tori and governed by differential angular velocities, we construct a Lagrangian description of scalar transport on a torus. The scalar field $\chi(s,\theta,t)$ evolves according to the advection equation $D\chi/Dt = 0$, with trajectories defined by coupled toroidal and poloidal motions. Starting from an initially localized Gaussian patch, we show that differential rotation along the torus leads to progressive stretching and folding, resulting in the formation of thin filamentary structures. Through a combination of three-dimensional surface visualization, meridional cross-sections, and unwrapped toroidal coordinates, we demonstrate that the scalar distribution undergoes systematic deformation characterized by longitudinal elongation and transverse compression. This leads to a rapid amplification of scalar gradients, with $\max|\nabla\chi|$ exhibiting near-exponential growth, while the transverse filament thickness decreases algebraically in time. The unwrapped representation reveals the underlying shear mechanism as a linear growth of phase differences, producing quasi-periodic layered structures. These results provide a clear geometric and dynamical interpretation of scalar mixing on invariant tori, highlighting the role of differential advection in generating fine-scale structures even in steady, integrable flows. The proposed framework links three-dimensional vortex dynamics with toroidal transport and offers insight into the early stages of mixing, as well as the precursors to nonlinear and dissipative effects in vortex-dominated flows.

Keywords: passive scalar transport; advection; filamentation; invariant tori; Hill vortex; toroidal coordinates; Lagrangian dynamics; differential rotation; shear flow; scalar mixing; vortex dynamics; meridional cross-section; gradient amplification; vortex-induced transport; coherent structures

1. Introduction. The problem of passive scalar transport in incompressible flows with closed streamlines has been studied extensively. Classical works in this area are associated with the analysis of differential advection and mixing in integrable flows [13-18]. In particular, the studies of P. B. Rhines and W. R. Young [16] demonstrated that even in fully regular flows with closed trajectories, effective "mixing" can occur due to the stretching and winding of a passive scalar. These works showed that the dependence of angular velocity on the invariant of motion leads to a linear growth of phase differences and, consequently, to filamentation.

These ideas were later developed in the context of geophysical flows and nonlinear dynamics, for example in the works of N. J. Balmforth [5, 6], where processes of stretching and the formation of thin layers in jet-like and vortical structures were investigated. However, these studies typically considered either two-dimensional models or passive scalar transport without explicit account of three-dimensional geometries such as toroidal surfaces.

From a geometric and dynamical perspective, the present formulation is directly related to the theory of invariant tori in Hamiltonian systems. The works of Vladimir Arnold and Jürgen Moser [3, 12] showed that in integrable systems the motion takes place on invariant tori parameterized by angular variables. In such systems, the dynamics can be written in the form

$$\dot{s} = \omega_s(I), \dot{\theta} = \omega_\theta(I), \qquad (1)$$

where I is the action variable (an analogue of ψ). The dependence of the frequencies on I gives rise to phase shifts and leads to the *winding* of trajectories. However, in the classical KAM theory [3], neither the distribution of a passive scalar nor its filamentation was considered. In this work, we therefore provide a physical interpretation that complements the classical Hamiltonian framework [9], extending it to the advection and deformation of a localized scalar field.

On the other hand, there exists an extensive body of literature in fluid dynamics devoted to vortex structures and their internal dynamics. The works of H. K. Moffatt [11] and S. Childress & A.D. Gilbert [7] investigated the stretching and deformation of vortex lines, as well as the topology of flow fields. However, the primary focus of these studies was on vortex dynamics itself, rather than on the transport of a passive scalar on invariant surfaces.

Finally, there is a well-established line of research known as chaotic advection [1-2], which demonstrates that even simple steady or time-periodic flows can generate highly complex scalar structures. The key distinction in the present case, however, is that the flow under consideration is integrable rather than chaotic. Despite this, it still produces complex scalar distributions due to the presence of shear. Thus, the complexity observed here arises not from chaotic trajectories, but from differential advection in a regular flow.

2. Advection. It should be noted that the problem of passive scalar transport in incompressible flows with closed streamlines is closely related to the fundamental concept of chaotic advection introduced by Hassan Aref. In his seminal work [1], Aref (1984) demonstrated that even simple laminar flows can generate highly complex scalar distributions through the mechanism of stretching and folding, described by the advection equation

$$D\chi/Dt = (\partial\chi/\partial t) + \mathbf{u}\cdot\nabla\chi\,. \quad (2)$$

In such systems, the complexity of the scalar structure is determined not by turbulence, but by the kinematics of trajectories and the properties of the flow as a dynamical system. In contrast to classical examples of chaotic advection, where the dynamics of Lagrangian trajectories is non-integrable and characterized by positive Lyapunov exponents, the motion in the present case remains regular and takes place on invariant toroidal surfaces. The particle trajectories are described by the system

$$ds/st = \omega_s(\theta), d\theta/dt = \omega_\theta\,, \quad (3)$$

where both frequencies are smooth functions, and the phase space contains no chaotic regions. Nevertheless, as emphasized in subsequent studies on Lagrangian kinematics, the key mechanism responsible for the formation of complex structures is not chaos per se, but rather the presence of shear, which leads to the linear growth of phase differences.

$$\Delta s(t) \sim \omega_s'(\theta)t\,. \quad (4)$$

Thus, the filamentation of the passive scalar shown in the figure can be viewed as a particular case of the more general framework proposed by Aref, in which stretching and winding act as universal mechanisms for the generation of fine-scale structure. However, in contrast to classical chaotic advection, where stretching is exponential and associated with chaotic trajectories, $|\delta x(t)| \sim e^{\lambda t}$, the flow in the present case remains integrable, and the increasing complexity of the scalar field is governed by differential advection on invariant tori. This leads to a quasi-linear growth of phase differences and an algebraic decrease of transverse scales,

$$\ell_\perp(t) \sim 1/(1+\Omega' t)\,, \quad (5)$$

accompanied by a simultaneous amplification of scalar gradients.

Thus, the obtained results extend the classical theory of Aref by demonstrating that the formation of thin filaments and effective "mixing" of a passive scalar can occur even in fully regular three-dimensional flows without chaos. In this sense, the dynamics considered here occupies an intermediate position between integrable systems and regimes of chaotic advection, combining the geometric regularity of trajectories with the kinematic complexity of the scalar distribution.

3. Problem formulation and governing equations. The underlying idea is that in an axisymmetric flow with closed streamlines, each level set $\psi = const$ in the meridional plane, when rotated about the axis of symmetry, generates a toroidal surface. If the motion of a particle along such a surface is then prescribed with two angular components -poloidal and toroidal - a localized patch of passive scalar is advected along trajectories, gradually stretching into a long, thin filament. Accordingly, the visualization is constructed as a schematic computational model of passive scalar transport on a toroidal surface. It does not represent a direct numerical solution of the full three-dimensional Euler equations for the Hill vortex, but rather a geometrically and kinematically consistent approximation. This approach allows one to clearly illustrate the processes of stretching, winding, and filamentation of a localized scalar patch on a family of toroidal stream surfaces.

The computational visualization is based on a Lagrangian simulation of passive scalar transport on an invariant toroidal surface, which approximates a family of streamlines in an axisymmetric flow. The construction begins with the specification of the torus geometry. In the standard parametrization, a torus with major radius R and minor (tube) radius a is described using two angular coordinates: the toroidal angle s and the poloidal angle θ. In Cartesian coordinates, this parametrization is given by

$$x = (R + a\cos\theta)\cos s\,, y = (R + a\cos\theta)\sin s\,, z = a\sin\theta\,, \quad (6)$$

where R is the major radius of the torus and a is the radius of the tube. All transport computations are carried out in the parametric coordinates(s, θ), which allows for the use of periodic boundary conditions and avoids complications associated with surface curvature. The numerical data are constructed in this parametric representation using the angular variables (s, θ) , где $s \in [0, 2\pi)$, the toroidal angle, and $\theta \in [-\pi, \pi)$ the poloidal angle. The geometry of the surface is defined through the standard mapping into three-dimensional space given by equations (6). Such a surface serves as a three-dimensional analogue of a single invariant torus in the Hill vortex: in the physical problem, its shape is determined by the streamfunction, whereas in the present visualization it is replaced by an idealized circular torus in order to clearly illustrate the transport mechanism.

Next, a passive scalar field $\chi = \chi(s, \theta, t)$ is defined on this surface, which satisfies the pure advection equation:

$$D\chi/Dt = (\partial\,\chi/\partial t) + \dot{s}(\partial\,\chi/\partial s) + \dot{\theta}(\partial\,\chi/\partial\theta) = 0. \quad (7)$$

This implies that the scalar concentration is conserved along Lagrangian trajectories. Therefore, the problem reduces to prescribing the kinematics on the torus, i.e., specifying the evolution laws for $\dot{s}$ and $\dot{\theta}$. For the purposes of visualization, a simple model was adopted with constant poloidal velocity and differential toroidal velocity:

$$\dot{\theta} = \omega_\theta, \dot{s} = \omega_s(\theta)\,, \quad (8)$$

where $\omega_\theta = const$, and $\omega_s(\theta)$ is a smooth periodic function that generates differential advection. To reproduce winding and shear, the toroidal velocity was taken to depend on the position on the torus, for example in the form

$$\omega_s(\theta) = \omega_0 + \varepsilon\cos\theta, \quad (9)$$

or in an equivalent form with smooth periodic modulation. The parameters ω_0 and ε were chosen so as to ensure a noticeable phase shift while preserving the regular (non-chaotic) structure of the trajectories.

The resulting velocity field is divergence-free on the toroidal surface and preserves measure, which corresponds to the condition

$$\nabla_s \cdot \boldsymbol{u}_\tau = 0, \quad (10)$$

where $\boldsymbol{u}_\tau$ denotes the divergence-free tangential velocity field on the toroidal surface.

It is precisely this dependence of ω_s on θ in equation (9) that generates **differential advection**: different parts of the scalar patch, located at slightly different poloidal positions, move along the torus with different velocities. As a result, the phase shift between two nearby particles grows in time as

$$\Delta s(t) \approx \omega_s'(\theta)\Delta\theta\, t\,, \quad (11)$$

and the patch is stretched into a long filament.

At the initial moment, the scalar field is prescribed as a localized Gaussian patch on the torus:

$$\chi(s,\theta,0) = \exp(-((s-s_0)/m_s)^2 - ((\theta-\theta_0)/m_\theta)^2)\,, \quad (12)$$

where $m_s = \sqrt{2}\sigma_s$ and $m_\theta = \sqrt{2}\sigma_\theta$.

Since the angular variables are periodic, the numerical implementation accounts for periodic continuation in both s and θ, meaning that distances are measured along the shortest arc on the circle. The solution at any time is then expressed in Lagrangian form as:

$$\chi(s,\theta,t) = \chi_0\big(S_{-t}(s,\theta), \Theta_{-t}(s,\theta)\big), \quad (13)$$

where (S_t, Θ_t) denotes the flow map generated by the dynamical system

$$ds/dt = \omega_s(\theta)\,, d\theta/dt = \omega_\theta\,. \quad (14)$$

In other words, to obtain the scalar concentration at a point (s,θ) at time t, one must trace this point backward along its trajectory and evaluate the initial field at the corresponding location. In a discrete visualization, this can be achieved either by integrating an ensemble of particles or by directly advecting a grid-based field. In the present implementation, a Lagrangian approach was employed: a set of tracer points carrying scalar values χ, was constructed, these particles were then advected along trajectories, and subsequently a smoothed scalar field on the toroidal surface was reconstructed from their distribution.

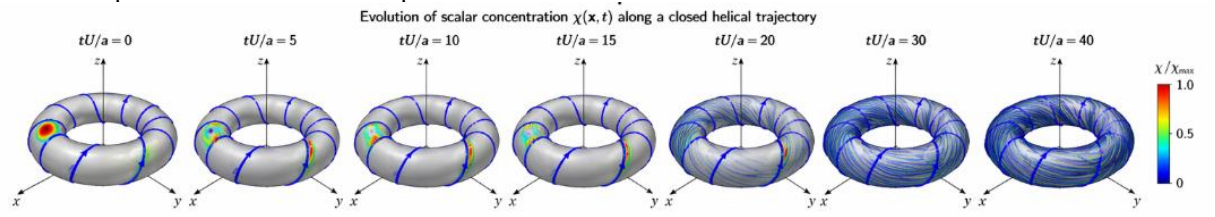

Figure 1. *Evolution of scalar concentration $\chi(x,t)$ along closed helical trajectories on a torus*

4. Visualization of scalar advection and results. To obtain the first row of figures (Fig. 1) from the described dynamics, the torus was visualized as a three-dimensional surface colored according to the scalar field $\chi(x,y,z,t)$. For this purpose, each point on the surface with parameters (s,θ) was mapped into Cartesian coordinates (x,y,z) using the parametrization given above, and the value $\chi(s,\theta,t)$ was used to define the color. As a result, the first row clearly illustrates the evolution of the scalar patch: an initially compact region progressively elongates along trajectories and wraps around the torus. At early times, the structure appears as a single stretched patch; subsequently, it develops into a long, thin filament, and at later times it forms a system of multiple narrow, wound filaments.

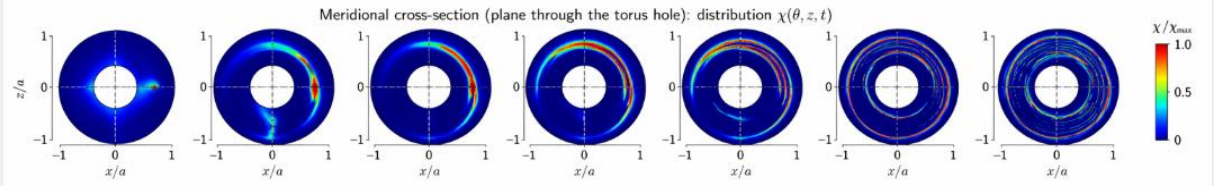

Figure 2. *Meridional cross-section of the torus (plane through the torus hole): evolution of scalar distribution $\chi(\theta,z,t)$*

The second row of Fig.2 corresponds to the **meridional cross-section** of the scalar distribution. To obtain this representation, a plane passing through the axis of the torus is considered, for example the plane $y = 0$, and the intersection of the colored surface with this plane is analyzed. In parametric coordinates, this is equivalent to examining the distribution $\chi(\theta,z,t)$ or, after mapping to Cartesian coordinates, the field $\chi(x,z,t)$ within an annular domain. This cross-section clearly shows how the initially localized scalar patch evolves: first forming an elongated arc, then a thin layer, and eventually several nearly concentric narrow bands. The key significance of this representation is that it provides not only the distribution on the surface, but also its projection onto a more familiar two-dimensional plane, where the process of filamentation is more readily observed.

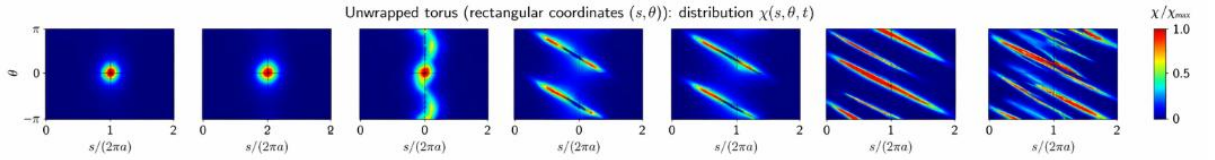

Figure 3. *Unwrapped torus (rectangular coordinates (s,θ)): evolution of scalar distribution $\chi(s,\theta,t)$*

The next row of Figure 3 is constructed in the so-called unwrapped toroidal coordinates. Since the surface of a torus is topologically equivalent to the product of two circles $S^1 \times S^1$, it can be "*cut*" and mapped onto a rectangle in the (s, θ) coordinates following the approach of Arnold [3]. In this representation, scalar transport becomes particularly transparent. In these coordinates, the initial Gaussian patch appears as a compact spot in the rectangular domain; subsequently, due to the non-uniform velocity $\dot{s}$, the patch deforms into an inclined band and then into a family of nearly parallel slanted filaments that periodically extend across the boundaries. It is precisely in this representation that the dominant mechanism – shear - becomes most evident. If the velocity ω_s were constant, the patch would be advected without deformation. However, since $\omega_s'(\theta) \neq 0$, a linear growth of phase differences occurs, accompanied by transverse compression. In the unwrapped coordinates, this can be estimated as follows: if the local longitudinal scale grows as

$$\ell_{\parallel}(t) \sim \ell_0(1 + \omega_s'(\theta)\, t), \qquad (15)$$

then the transverse scale decreases as

$$\ell_{\perp}(t) \sim \ell_0/(1 + \omega_s'(\theta)t)\,, \qquad (16)$$

under the condition of area preservation in an incompressible (divergence-free) transport on the surface.

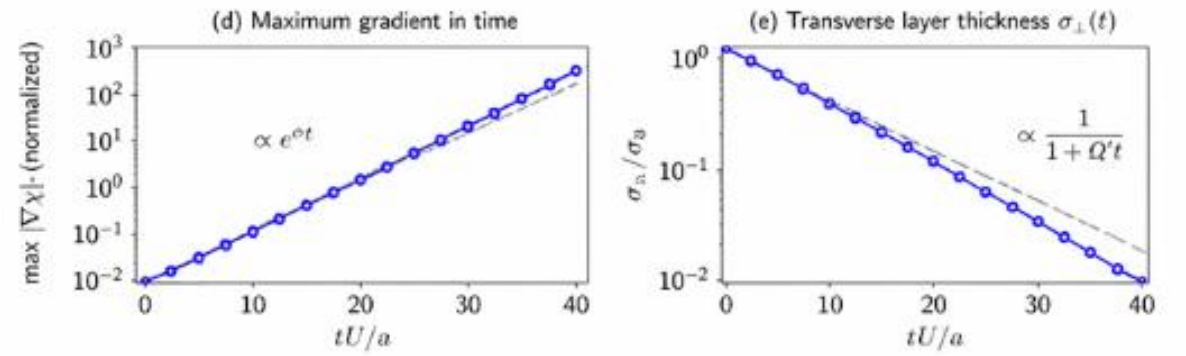

Figure 4. *Panels (d) and (e) illustrate the quantitative characteristics of the filamentation process of the passive scalar over time. Panel (d) shows the evolution of the maximum scalar gradient $max|\nabla\chi|$, normalized by its initial value. It is observed that $max|\nabla\chi|$ increases monotonically and, when plotted on a logarithmic scale, exhibits an approximately linear dependence on time, which corresponds to an exponential law $max|\nabla\chi| \propto exp\, \sigma t$.*

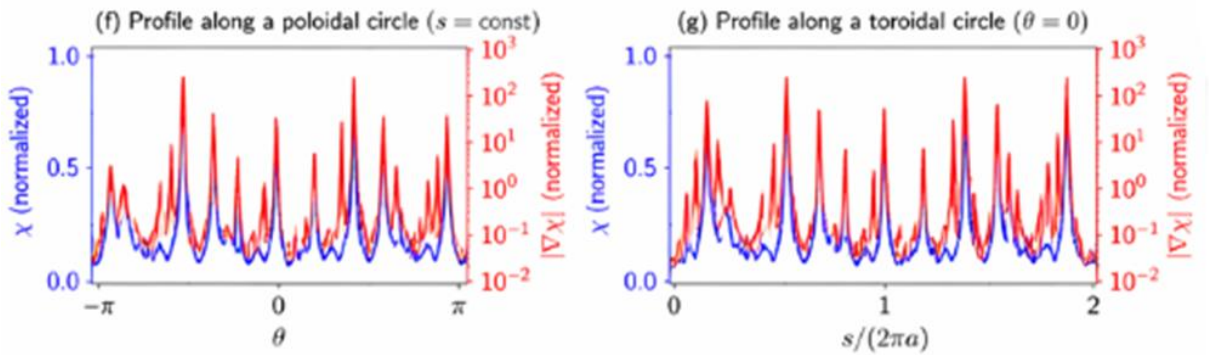

Figure 5. *Panels (f) and (g) show one-dimensional profiles of the passive scalar χ and the magnitude of its gradient $|\nabla\chi|$ at a late stage of the evolution. Panel (f) presents the profile along a poloidal circle ($s = const$), тогда как на графике (g) shows the profile along a toroidal circle (θ=0). In both cases, the values of χ (blue curve) and $|\nabla\chi|$ (red curve) are normalized, with the gradient plotted on a logarithmic scale.*

For quantitative diagnostics, additional plots of gradient growth and transverse thickness decay were included (Fig. 4). The scalar gradient on the toroidal surface is, in principle, computed as a derivative with respect to the intrinsic coordinates, taking into account the surface metric. However, for visualization purposes, a normalized quantity equivalent to

$$|\nabla\chi| \sim \sqrt{(\partial\chi/\partial s)^2 + (\partial\chi/\partial\theta)^2}\,. \qquad (17)$$

As the *winding* process develops, the scalar filaments become progressively thinner, leading to an increase in $|\nabla\chi|$. This behavior is reflected in the plot as an approximately exponential (or quasi-exponential) growth of the maximum gradient, $\max|\nabla\chi(t)| \sim e^{\sigma t}$, which is consistent with strong stretching and compression. At the same time, the effective transverse thickness $\sigma_{\perp}(t)$, was evaluated, which in the model decreases as

$$\sigma_{\perp}(t) \sim 1/(1 + \Omega' t)\,, \qquad (18)$$

that is, in accordance with the kinematic model of differential winding.

Finally (Fig. 5), one-dimensional profiles were computed along a fixed poloidal circle and a fixed toroidal circle. For this purpose, the sections

$$\chi(\theta, t)|_{s=s_0} \text{ and } \chi(s, t)|_{\theta=\theta_0}\,, \qquad (19)$$

were considered, along with the corresponding profiles of $|\nabla\chi|$. At late times, these profiles acquire an oscillatory structure with a large number of narrow peaks. This indicates that the scalar is no longer con-

centrated in a single localized patch, but is instead distributed over a multitude of thin filaments that wrap repeatedly around the torus.

Thus, the construction of the figure 4 involves the following sequence of steps: first, the toroidal geometry is defined in parametric coordinates; next, an initial localized scalar distribution $\chi(s,\theta,0)$ is prescribed; then, a steady divergence-free velocity field with a non-uniform toroidal component is introduced on the surface; the scalar field is subsequently advected in a Lagrangian manner along trajectories determined by the system for $s(t)$ and $\theta(t)$; the concentration field is then reconstructed and visualized in three forms - on the toroidal surface, in a meridional cross-section, and in the unwrapped (s,θ); domain; finally, diagnostic quantities such $\max|\nabla\chi|$, $\sigma_{\perp}(t)$ and one-dimensional profiles are evaluated. The purpose of this visualization is to clearly demonstrate a fundamental mechanism: a localized scalar in a closed three-dimensional flow does not dissipate, but is conserved along trajectories and, under the action of differential advection, is stretched into long, thin filaments that become increasingly tightly wound around the toroidal surface. This provides a geometric picture of advection and filamentation of a passive scalar in three-dimensional space.

5. Discussion. The numerical results demonstrate that, in the absence of diffusion and under a steady velocity field, the dominant mechanism governing the evolution is purely kinematic stretching. As time increases, the initially localized scalar patch is elongated along trajectories, forming thin layers whose thickness decreases while the gradients increase. At later times, the structure becomes multilayered, and the scalar distribution acquires a quasi-periodic character in both the toroidal and poloidal directions. These computational results confirm the theoretical prediction [10, 16] that differential advection along closed trajectories leads to filamentation and the generation of progressively smaller scales even in fully regular three-dimensional flows.

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MEDICAL SCIENCES

CLINICAL AND MICROBIOLOGICAL CHARACTERISTICS OF ACUTE TONSILLITIS IN CHILDREN AND ADULTS

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Abstract

Acute tonsillitis is one of the most common infectious diseases of the upper respiratory tract, characterized by inflammatory lesions of the palatine tonsils and significant variability of clinical manifestations. Despite the traditional view of the leading role of bacterial pathogens, modern studies indicate a significant role for viral agents and opportunistic microbiota.. The aim of this study was to examine the microbiological composition of palatine tonsils in patients with acute tonsillitis across different age groups and to identify possible etiological factors of the disease.

The study involved 45 people, including 30 patients with acute tonsillitis and 15 healthy control patients. A bacteriological study of smears from the palatine tonsils was performed, followed by identification of the microorganisms. It was found that in most cases, opportunistic microflora prevails, while the frequency of detection of classical bacterial pathogens remains low.

The results confirm the significant role of viral etiology in the development of acute tonsillitis and justify the need to rationalize antibacterial therapy based on microbiological data.

Keywords: acute tonsillitis, microbiota, viral infection, *Streptococcus pyogenes*, antibiotic resistance.

Introduction

Acute tonsillitis occupies a leading position among infectious diseases of the upper respiratory tract and is a frequent reason for patients to seek medical help. A particularly high incidence is observed among school-age children, which is associated with the immaturity of the immune system and the high intensity of contacts within groups. In adult patients, the disease also occurs frequently and may be accompanied by complications, particularly peritonsillar abscesses or systemic reactions [1].

For a long time, the etiology of acute tonsillitis was considered mainly in terms of bacterial infection, with emphasis on group A β-hemolytic streptococcus *(Streptococcus pyogenes*) [2, 3]. At the same time, modern data indicate that a significant proportion of cases have a viral origin, particularly adenoviruses, influenza viruses, parainfluenza viruses, rhinoviruses, and Epstein-Barr virus. This significantly complicates the differential diagnosis and the selection of optimal therapeutic strategies [4].

A key role in the pathogenesis of the disease is played by the palatine tonsil microbiota. Normally, it is represented by a variety of symbiotic microorganisms that provide colonization resistance. Disruption of this balance can contribute to the development of inflammation even in the absence of classical pathogens [5].

In view of this, it is relevant to study the microbiological features of acute tonsillitis, taking into account age differences, which was the purpose of this study.

The study was prospective and comparative, and involved patients across different age groups. The main group consisted of 30 people with a clinically confirmed diagnosis of acute tonsillitis. It included 18 children aged 5 to 14 and 12 adults aged 20 to 40. The control group consisted of 15 individuals who were practically healthy and without signs of acute respiratory disease.

The inclusion criteria were the presence of typical clinical manifestations of acute tonsillitis (sore throat, tonsil hyperemia, plaques, fever). The exclusion criteria were prior administration of antibacterial drugs within the last 14 days and the presence of chronic diseases during the exacerbation phase.

The biological material was collected with sterile swabs from the palatine tonsil surfaces in the morning, before meals. The obtained samples were immediately transported to the laboratory for further bacteriological examination.

Cultivation was carried out on standard nutrient media, and microorganisms were subsequently identified based on morphological, cultural, and biochemical properties. A quantitative assessment was carried out, accounting for the intensity of colony growth.

Statistical analysis included determination of relative frequencies and mean values, and assessment of the reliability of differences using the χ^2 criterion. The level of statistical significance was accepted at $p<0.05$.

The analysis revealed that the microbiological spectrum in patients with acute tonsillitis is characterized by significant diversity and heterogeneity. The most common were opportunistic microorganisms, particularly *Streptococcus viridans*, which were detected in 55% of cases. The obtained data indicate the dominance of commensal and opportunistic flora in the palatine tonsil microbiota during the acute inflammatory process.

The frequency of detection of classical bacterial pathogens was significantly lower. Thus, *Streptococcus pyogenes* was identified in only 10% of patients, and *Staphylococcus aureus* in 8%. Comparison of the frequency of detection of opportunistic microbiota and obligate pathogens showed a statistically significant difference ($\chi^2=6.12$; $p<0.05$), which confirms the predominance of non-pathogenic or opportunistic microorganisms in the study group.

In the control group, normal symbiotic microorganisms predominated, accounting for about 70% of the microbiota. At the same time, pathogenic bacteria were not detected in any case. Comparative analysis between the main and control groups demonstrated statistically significant differences in the frequency of pathogen detection ($\chi^2=5.48$; $p<0.05$), confirming their association with the inflammatory process.

Age analysis showed certain differences in the microbiological spectrum. In children, the detection rate of *Streptococcus pyogenes* was 12%, while in adults, 8%. At the same time, *Staphylococcus aureus* was more often detected in adults (10%) compared to children (6%). However, these differences did not reach statistical significance ($p>0.05$), which may be due to the limited sample size.

The detection frequency of *Streptococcus viridans* was similar in children (57%) and adults (52%), and no statistically significant differences were observed ($p>0.05$). This indicates the relative stability of colonization by opportunistic microbiota across age groups.

Thus, the results of statistical analysis confirm that in acute tonsillitis, opportunistic microbiota prevails, while classical bacterial pathogens play a less significant role. The absence of significant age differences indicates the universality of the revealed patterns.

Table 1

Distribution of microorganisms in patients with acute tonsillitis

Microorganism	Children (%)	Adults (%)	Total (%)
Streptococcus viridans	57	52	55
Streptococcus pyogenes	12	8	10
Staphylococcus aureus	6	10	8
Other bacteria	10	12	11
Normal microbiota	15	18	16

The results indicate the complex, multifactorial nature of acute tonsillitis etiology. The predominance of opportunistic microbiota can be considered a manifestation of dysbiosis arising from a viral infection or a decrease in local immunity.

The low frequency of *Streptococcus pyogenes* detection is consistent with modern studies that show that only a subset of cases of acute tonsillitis are of bacterial origin [6, 7]. This is of fundamental importance for clinical practice, as excessive antibiotic use contributes to the development of antibiotic resistance [8, 9].

An important aspect is also the role of viruses that are not detected by standard bacteriological methods. This necessitates the use of additional diagnostic approaches, such as molecular genetic methods [10, 11].

In addition, the results emphasize the importance of an individualized approach to treatment, accounting for the clinical picture, patient age, and laboratory data.

The study allowed us to establish that, in most cases, acute tonsillitis is associated with the predominance of opportunistic microbiota and a relatively low frequency of detection of classical bacterial pathogens. This confirms the significant role of viral infection in the development of the disease.

Conclusion

The obtained data justify the need to review approaches to the selection of antibacterial therapy and to introduce modern diagnostic methods. A promising direction is the further study of the interaction between the microbiota and the immune system, which may contribute to the development of new approaches to the prevention and treatment of acute tonsillitis.

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PEDAGOGICAL SCIENCES

THE STRUCTURAL-FUNCTIONAL MECHANISM FOR THE DEVELOPMENT OF MANAGEMENT COMPETENCE IN FUTURE TEACHERS

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СТРУКТУРНО-ФУНКЦИОНАЛЬНЫЙ МЕХАНИЗМ ФОРМИРОВАНИЯ УПРАВЛЕНЧЕСКОЙ КОМПЕТЕНТНОСТИ БУДУЩИХ ПЕДАГОГОВ

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Abstract

Contemporary international requirements in the education system, which emphasise disciplinary and methodological knowledge and the level of development of managerial competencies, have significantly expanded the professional role of teachers. The aim of this article is to theoretically substantiate and describe the mechanism for developing managerial competence in future teachers, taking into account contemporary pedagogical approaches and principles. The study is based on a theoretical analysis of management concepts and a simulation of the mechanism by which future teachers develop their managerial competence.

The theoretical significance of this study lies in identifying the structure of the interrelated components of managerial competence, comprising motivational-value, cognitive, operational-behavioural and reflective components. The practical value of this work lies in the potential for applying the mechanism for developing managerial competence within the educational process. The proposed mechanism for developing the managerial competence of future teachers facilitates the development of the individual as a subject of professional reflection and self-development. Consequently, the development of managerial competence involves the targeted cultivation of the ability to analyse one's own professional practice, to understand managerial decisions, and to evaluate their effectiveness.

Аннотация

Современные международные требования в системе образования, выдвигая на первый план владение дисциплинарно-методическими знаниями и уровень сформированности управленческих компетенций значительно расширили профессиональную роль педагогов. Цель данной статьи — теоретически обосновать и описать механизм формирования управленческой компетентности будущих педагогов с учетом современных педагогических подходов и принципов. Исследование основано на теоретическом анализе управленческих концепций и моделировании механизма формирования управленческой компетентности будущих педагогов.

Теоретическая значимость исследования заключается в определении структуры взаимосвязанных компонентов управленческой компетентности, включающая мотивационно-ценностный, когнитивный, операционно-деятельностный и рефлексивный компоненты. Практическая ценность работы состоит в возможности применения механизма формирования управленческой компетентности в образовательный процесс. Представленный механизм формирования управленческой компетентности будущих педагогов обеспечивает становление личности как субъекта профессиональной рефлексии и саморазвития. В результате формирование управленческой компетентности предполагает целенаправленное развитие способности к анализу собственной профессиональной деятельности, осознанию управленческих решений и оценке их эффективности.

Keywords: managerial competence, organisational, managerial and reflective abilities, components of managerial competence, the mechanism for developing managerial competence, managerial role.

Ключевые слова: управленческая компетентность, организационно-управленческие и рефлексивные способности, компоненты управленческой компетентности, механизм формирования управленческой компетентности, управленческая роль.

Введение

Сегодня во всем мире происходящие изменения в образовательных системах, значительно трансформируют профессиональную роль педагогов. Помимо функциональных обязанностей по обучению, от педагогов все чаще ожидается участие в планировании образовательных процессов, координации и управлении деятельностью субъектов образовательного процесса, принятии педагогических решений и эффективном взаимодействии с различными заинтересованными сторонами (OECD, 2021; UNESCO, 2016). В современных условиях предъявленные задачи требуют сформи-

рованность управленческой компетентности у будущих учителей в процессе профессиональной подготовки. Внедрение в подготовительную практику данного положения должно обеспечивать усвоение дисциплинарных знаний и навыков, развить организационно-управленческих и рефлексивных способностей (Želvys, Zhunusbekova, & Askarkyzy, 2023; Kaliyeva & Gabiden, 2021). Однако во многих программах подготовки педагогов управленческая компетентность формируется фрагментарно без четкой структуры и системной педагогической поддержки.

Теоретические исследования рассматривают управленческую компетентность с системного, личностно-ориентированного и деятельностного подходов (Nikitovskaya, 2019). Тем не менее анализ существующих исследований выявляет отсутствие единых и структурированных механизмов, специально направленных на формирование управленческой компетентности на этапе подготовки будущих педагогов (Junisbaeva & Begalieva, 2025). Большинство моделей ориентированы либо на практикующих педагогов, либо на образовательных менеджеров, тогда как формирующий потенциал начальной подготовки педагогов остается недостаточно представленным.

Это указывает на необходимость разработки обоснованного механизма, который интегрирует мотивационные, когнитивные, практические и рефлексивные компоненты и обеспечивает последовательное формирование управленческой компетентности будущих педагогов. Такой механизм отвечает современным образовательным стандартам и обеспечивает качественную подготовку педагогов независимо от формы и уровня образовательного процесса.

Таким образом, цель статьи — теоретически обосновать и описать механизм формирования управленческой компетентности будущих педагогов в условиях современного образования. Предложенный механизм направлен на совершенствование программ подготовки педагогов и повышение профессиональной готовности будущих педагогов к эффективной организации и управлении образовательным процессом.

Понятие управленческой компетентности будущих педагогов

Понятие управленческой компетентности широко обсуждается в образовательных исследованиях в контексте лидерства, образовательного управления и профессиональной эффективности (Elliott Jaques, 2017; Mirsoliyeva, 2019; Burnakin, 2021; Kaliyeva K. M. & Gabiden R., 2021; Želvys, Zhunusbekova, & Askarkyzy, 2023). В современной педагогике управленческая компетентность понимается как интегративная характеристика, объединяющая знания, навыки, личностные качества и профессиональные ценности, позволяющая эффективно организовывать, регулировать и оценивать образовательную деятельность.

В этой связи, в процессе подготовки педагогов управленческая компетентность приобретает характерные особенности из-за многофункциональности профессиональной роли педагогов. Будущие педагоги должны овладеть предметным содержанием и методикой преподавания дисциплин, а также развивать способности планировать образовательные процессы, управлять деятельностью учащихся, принимать обоснованные управленческие решения и принимать участие в практике самоанализа (Kaliyeva & Gabiden, 2021). Таким образом, управленческая компетентность на этапе подготовки будущих педагогов должна рассматриваться как фундаментальная составляющая будущей профессиональной деятельности, а не как дополнительный навык.

С теоретической точки зрения управленческая компетентность чаще всего анализируется через системный подход, который подчеркивает взаимосвязь структурных компонентов и компетентностный подход, который акцентирует внимание на результатах обучения и профессиональной готовности (Elliott Jaques, 2017; Mirsoliyeva, 2019; Burnakin, 2021; Kaliyeva K. M. & Gabiden R., 2021; Želvys, Zhunusbekova, & Askarkyzy, 2023; Junisbaeva & Begalieva, 2025). Эти исследования позволяют осмыслить управленческую компетентность как динамическую постепенно развивающуюся систему в процессе профессиональной подготовки.

На основе анализа литературы управленческая компетентность будущих педагогов, на наш взгляд, может быть структурирована в несколько взаимосвязанных компонентов.

КОМПОНЕНТЫ УПРАВЛЕНЧЕСКОЙ КОМПЕТЕНТНОСТИ В ПОДГОТОВКЕ БУДУЩИХ ПЕДАГОГОВ
МОТИВАЦИОННО-ЦЕННОСТНЫЙ КОМПОНЕНТ
КОГНИТИВНЫЙ КОМПОНЕНТ
ОПЕРАЦИОННО-ДЕЯТЕЛЬНОСТНЫЙ КОМПОНЕНТ
РЕФЛЕКСИВНЫЙ КОМПОНЕНТ
отражает осознание будущими педагогами значимости управленческих функций и готовность брать на себя ответственность за организацию образовательного процесса
включает знания об образовательном менеджменте, планировании, нормативных рамках и стратегиях коммуникации
охватывает практические навыки, связанные с принятием решений, организацией, координацией и решением проблем в образовательном контексте
предполагает самоанализ, оценку собственных действий и способность корректировать профессиональное поведение на основе опыта и обратной связи

Рис. 1 Структура взаимосвязанных компонентов управленческой компетентности в подготовке будущих педагогов

Формирование управленческой компетентности на этапе подготовки будущих педагогов характеризуется как готовность к будущей управленческой деятельности. Следовательно, образовательная среда педагогических вузов играет решающую роль в создании условий для поэтапного и системного развития управленческой компетентности у студентов.

Методологические основы исследования

Хотя исследование носит теоретический характер, оно опирается на четко определённую методологическую базу, обеспечивающую последовательность, достоверность и научную обоснованность выводов (Želvys, Zhunusbekova, & Askarkyzy, 2023). В исследовании используется системный подход, позволяющий рассматривать управленческую компетентность будущих педагогов как целостную и динамическую систему, состоящую из взаимосвязанных компонентов.

В рамках компетентностного подхода управленческая компетентность рассматривается как образовательный результат, отражающий готовность будущих педагогов выполнять управленческие функции в профессиональной деятельности (Kaliyeva & Gabiden, 2021).

Кроме того, исследование опирается на личностно-ориентированный и деятельностный подходы, которые подчеркивают роль целенаправленной деятельности в формировании профессиональных компетенций. С этой точки зрения управленческая компетентность развивается через участие будущих педагогов в образовательных ситуациях, требующих планирования, организации, принятия решений и самоанализа собственной деятельности (Nikitovskaya, 2019; Junisbaeva & Begalieva, 2025).

Используемые методы исследования включают теоретический анализ педагогической и управленческой литературы, сравнение международных подходов к развитию компетенций и педагогическое моделирование. Эти методы позволяют выявлять общие закономерности и компоненты управленческой компетентности, на основе которых следует разрабатывать структурированный механизм формирования управленческой компетентности у будущих педагогов.

Механизм формирования управленческой компетентности будущих педагогов

Основная цель предложенного механизма — обеспечить постепенное и устойчивое формирование управленческой компетентности будущих пе-

дагогов в соответствии с современными требованиями. Она достигается через интеграцию управленческого содержания в образовательные программы и создание условий, стимулирующих активное участие и рефлексию.

Эффективность механизма обеспечивается интеграцией управленческого содержания в учебный план, моделированием управленческих ролей и систематической организацией рефлексивных занятий с помощью интерактивных методов обучения. Механизм формирования управленческой компетентности будущих педагогов развивает навыки планирования, принятия обоснованных решений и постоянным профессиональным саморазвитием.

Обсуждение

Предложенный механизм предлагает системный и теоретически обоснованный подход, интегрирующий мотивационный, когнитивный, операционно-деятельностный и рефлексивный компоненты. В отличие от существующих моделей, он направлен на последовательное формирование компетентности. Внедрение механизма формирования управленческой компетентности в образовательный процесс обеспечивает становление будущего педагога как субъекта профессиональной ре-

флексии и саморазвития предполагает целенаправленное развитие способности к анализу собственной профессиональной деятельности, осознанию управленческих решений и оценке их эффективности.

Международные исследования подтверждают актуальность развития управленческой компетентности в педагогическом образовании OECD (2021) и UNESCO (2016) подчеркивают необходимость подготовки педагогов к сложным образовательным ролям в рамках преподавания дисциплин. Данный механизм соответствует международным приоритетам, предоставляя структурированную основу для формирования управленческой готовности будущих педагогов. Принципы рефлексивности и практической направленности соответствуют признанным педагогическим теориям. Механизм объединяет различные теоретические подходы в единую систему, специально адаптированную для будущих педагогов. С практической точки зрения разработанный механизм может служить в профессиональной подготовке выпускников к управленческим обязанностям.

Заключение

Исследование теоретически обосновывает механизм формирования управленческой компетентности будущих педагогов. Интеграция мотивационно-ценностного, когнитивного, операционно-деятельностного и рефлексивного компонентов в рамках педагогических условий обеспечивает системный характер формирования управленческой компетентности будущих педагогов. Такая интеграция обеспечивает целостность образовательного процесса, согласованность его содержания, форм и методов, а также устойчивое развитие способности к эффективному осуществлению управленческой деятельности. Таким образом, внедрение механизма позволяет повысить способность будущих педагогов планировать, организовывать и управлять образовательной деятельностью, одновременно развивая навыки самоанализа и профессионального развития.

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THE ROLE OF TRANSFORMATIONAL LEADERSHIP MODEL FOR ENHANCING SCHOOL PERFORMANCE IN SPECIALIZED SCHOOLS OF UZBEKISTAN

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Abstract

The following research study examines the model of transformational leadership and its impact on quality education and learning environment among specialized schools in Uzbekistan. The approach highlights the importance of visionary leadership in fostering high quality education, student performance and teacher retention. Through the integration of transformational leadership principles like idealized influence, intellectual stimulation, individualized consideration and inspirational motivation, the following framework can help school leaders across Uzbekistan to empower their teams, promote innovative teaching methodologies and establish a shared organizational vision. The study presents various strategies in addressing systemic barriers in education including resource allocation, socio-economic challenges and change resistance. Stakeholder engagement is prioritized, and the study proposes a collaboration between school leaders, teachers, parents, policymakers and communities to ensure sustainable development of education. The findings illustrate how transformational leadership can result in measureable improvements in student performance, institutional resilience and teacher retention.

Keywords: transformational leadership, specialized schools, Uzbekistan

1.1 Introduction

In the 21st century, education has become an integral part of the development of a country, especially in a country like Uzbekistan, where the government has placed immense responsibility of ensuring the future of the nation. At the same time, education system of Uzbekistan continues to face number of challenges such as resource constraints, difference of education quality as well as disparities in access. Hence, the government took number of innovative initiatives to provide equitable and high-quality education to all citizens of Uzbekistan including establishing Presidential, specialized and creative schools in all 214 districts of the country. In order for these schools to perform on high levels, transformational leadership can be seen as the tool to foster change, inspiration and vision, along with overcoming any challenges that may present themselves on the path.

1.2 Background and Context

The world governments have come together in providing quality education to all via initiatives like the Sustainable Development Goal (SDG4) proposed and being carried out by the United Nations, with the focus on equitable and inclusive education to all citizens of our planet by 2030. (Nations, 2026) However, even with the recent reforms in education, accessibility may not be provided to some school students in remote areas of the country. In addition, there are certain barriers like shortage of teachers, infrastructure being inadequate as well as systematic inefficiencies that continue to hinder the educational development. Moreover, hundreds of school leaders across the nation may be fixated on adopting traditional leadership approaches that help ensure the status quo and be occupied with administrative tasks. These approaches may be useful in managing the operational needs, but more often fails to address various modern challenges such as developing students with the demands of the 21st century and using technological advancements in improving learning environment. Therefore, one may look into transformational leadership, an approach that focuses on empowerment, collaboration and visionary thinking. As a result, school leaders could inspire change within their organizations, improving school performance and remove any accessibility barriers that exist.

1.3. Transformational Leadership in Education

It is no secret that transformational leadership has been praised as it provides the chance to motivate individuals while organizations continue to exceed expectations, and the student performance improves in the long run. The following leadership style possesses four components including individualized consideration, intellectual stimulation, inspirational motivation and idealized influence.[34] Once a school leader embraces these principles and applies them within the school, there is a high probability of innovative culture being cultivated, while team collaboration starts forming and continuous improvement is put in place. Transformational leader in a school can foster professional development among the staff and set high expectations throughout the organization, while encouraging creative problem-solving skills among educators as well as students. Furthermore, a leader with a transformational approach can inspire inclusivity and academic excellence, which can be adopted as a shared vision, and could propel all stakeholders to work collaboratively, leading to achieving the organizational goal of prosperity. It can be said that the following method continues to enhance the education quality but also prepare the school to be more adaptable and responsive to the ever-evolving needs of communities and students. While not common in specialized schools, transformational leadership provides the right tools to overcome systematic inequalities in

[34] Bass, B. M., & Riggio, R. E. (2006). Transformational Leadership (2nd ed.). Lawrence Erlbaum Associates. – The foundational theoretical framework for transformational leadership, outlining its four key components: idealized influence, inspirational motivation, intellectual stimulation, and individualized consideration.

public schools as inclusivity and equity can be addressed through effective decision-making processes. At the same time, the leaders of regional education branches of the Ministry of Preschool and School education of the Republic of Uzbekistan can engage with different stakeholders and advocate for marginalized populations, which can help with identifying and overcoming barriers to education including cultural biases, socioeconomic disparities and geographic isolation. The following approach promotes proactive problem-solving, helping students with diverse backgrounds to thrive in the classroom.

2. Literature Review

It is undeniable that transformational leadership has become the go to model to address various multifaceted challenges in the education systems of countries around the world. The main advantage of approach is equipping school leaders to inspire and empower their staff members, with the style being suited to tackle critical areas of education including solving accessibility problems in marginalized populations and enhancing the learning environment and teaching quality. The following literature review examines the theoretical foundations, how transformational leadership is applied and its impact on education, and hopes to provide insights into the aforementioned two objectives.

2.1 Transformational Leadership: Theoretical Foundations

Various past research projects highlighted how transformational leadership has helped leaders and their followers to collaborate in order to elevate the motivation and morale within the organizations. Moreover, further studies emphasized the core components of the approach: individualized consideration, intellectual stimulation, inspirational motivation and idealized influence (Dalkie & Botha, 2024). In the context of education, the following principles lead to ensuring that students are maximizing their potential, teachers being supported continuously, innovation being encouraged and a shared organizational vision is fostered.[35] In addition, studies in educational context provided examples where transformational school leaders played a crucial role in fostering collaborative and innovative environment (Sharma & Adeoye, 2024).

2.2 Transformational Leadership and Enhancing Quality Educational

Quality education encompasses positive learning environments, relevant curricula and effective teaching. Therefore, when a transformational leader is in charge of a school, they promote continuous professional development by inspiring and intellectually stimulating educators, fostering a continuous improvement culture. Recent studies pointed out that when transformational leadership is in effect, professional development opportunities pave way for higher student performance and teacher efficiency (Polatcan, Arslan, & Balci, 2023). Moreover, it has been proved in numerous occasions where school leaders with transformative approach encourage teamwork, whereby teachers share their best practices, which then leads to innovative instructional methods being shared.[36] At the same time, transformational leaders often engage with their students to understand their varying needs, which then helps in improving the learning environment and tailoring the teacher methods to meet those needs.

2.3 Transformational Leadership: Challenges and Critiques

As with the case of any type of leadership style, transformational leadership can have its drawbacks. One of the few is that in certain cases, school staff can sometimes become too dependent on a single visionary leader, which can be an issue when the institution is going through a leadership transition.[37] In addition, as it was previously stated, not all schools are sourced equally throughout Uzbekistan, which can be problematic when transformational leadership is being applied as change resistance and limited capacity are higher in these organizations. Last but not least, leaders are often subject to emotional challenges and demands, which ultimately can bring about a burnout and can undermine its effectiveness in the long-term.

2.4 Transformational Leadership: Integration of Objectives

A transformational leader would need to implement a holistic approach to ensure accessibility and high quality education. In order to accomplish that, they must be able to align strategic goals and organizational vision to emphasize on equity and educational excellence. Moreover, a leader should be able to build partnerships with local communities, NGOs and governments to overcome any systematic barriers that may be on the way. Data analysis skills of a leader also plays a crucial role in leveraging data for identifying any gaps in accessibility and quality, so that targeted interventions can be implemented.[38] Therefore, there needs to be a collaboration between stakeholders, and a leader should prioritize a culture of shared responsibility, one that leads to educational transformation. [28]. Hence, it can be said that transformational leadership possesses a

[35] Kareem, J., Patrick, H. A., Prabakaran, N., et al. (2023). Transformational educational leaders inspire school educators' commitment. Frontiers in Education, 8, 1171513. – This study found that transformational leadership significantly influenced different types of teacher commitment, including commitment towards the institution, student development, and self-development.

[36] Sianipar, A. (2024). The Role of Transformational Leadership in Improving School Performance: A Systematic Literature Review (SLR). SSRN Electronic Journal. – The systematic review confirmed that transformational leadership significantly improved school performance through teacher motivation, collaborative culture, and increased staff commitment.

[37] Kandemir, A. (2024). The mediating role of school effectiveness in the relationship between transformational leadership and workplace exclusion. Frontiers in Psychology, 15. – This study reveals that transformational leaders enable teachers to develop up-to-date teaching and learning approaches, allowing them to educate students according to the requirements of the age.

[38] Leithwood, K. (2021). A Review of Evidence about Equitable School Leadership. Education Sciences, 11(8), 377. – This review identifies school leadership practices and dispositions likely to help improve equitable school conditions and outcomes for diverse and traditionally underserved students.

key tool in enhancing quality of education and improving accessibility challenges in educational institutions. At the same time, it is recommended that future research to explore the ways of transformational leadership being tailored for specific contexts, and its impact being noticed in all public schools across the nation. Furthermore, the policymakers could also be developing frameworks that promote the development of transformational leadership so that there is a sustainable impact on Uzbekistan's education system.

3. Methodology

3.1 Research Design

The following research study utilizes a mixed-method design to evaluate transformational leadership, its effectiveness and implementation in improving education quality and learning environment in specialized schools within the system of the Agency for Specialized Educational Institutions under the Ministry of Preschool and school education of the Republic of Uzbekistan. This approach combines both quantitative and qualitative techniques to ensure the breadth and depth of understanding.

Qualitative Approach: Number of interviews and focus group sessions were carried out among the school leaders and staff members of specialized schools across all 14 regions of Uzbekistan. The processes focused on contextual challenges, perspectives of the stakeholders and leadership practices.

Quantitative Approach: Study also used statistical data analysis, particularly the performance of students and development of teachers through 2025 and first quarter of 2026, while surveys were used to rate the educational quality through the feedback of students to measure the impact of transformational leadership.

3.2 Sampling and Study Population

The study's population consists of school principals, teachers, technical staff members, and students of specialized schools in Uzbekistan. As there are over 210 specialized schools in almost all districts of the country, both rural and urban settings are covered for diverse contexts.[39]

Sampling Technique: The study employs purposive and stratified random sampling for qualitative and quantitative data collection respectively, where teachers and principals were selected according to their roles in the schools, while the study stratified schools based on their location to diversify the varying backgrounds of schools.

Sample Size: 40 school leaders, 20 focus groups (teachers and students).

Quantitative: 500 participants.

3.3 Methods of Data Collection

Qualitative

School leaders were invited for semi-structured interviews to find out the leadership challenges they face and strategies they employ. In addition, focus group sessions were carried out to understand the diverse perspectives of students and teachers on educational quality at their respective institutions. Moreover, the school's mission statements and school policies were examined to compare with the ongoing process of leadership.

Quantitative

The study also used structured questionnaires which were distributed online via Google survey platform to evaluate how the students and staff members rate the transformational leadership practices in their schools and whether they consider them to be efficient. The study also collected data on attendance rates, overall morale and feedback on the learning environment of the institution.

3.4 Transformational Leadership Intervention

As not all school leaders comprehend the varying styles of leadership that they could be taking advantage of, the author developed a tailored program of transformational leadership that was implemented in 10 specialized schools over five months. The program consisted of leadership training workshops (emphasis on the development of core competencies such as fostering collaboration, staff motivation and vision-building), peer network (leaders shared their experiences through bi-monthly Zoom meetings) and school-level action plans (school principals had to implement targeted initiatives in improving educational quality and overall learning environment).

3.5 Data Analysis

Qualitative Analysis: The study analyzed the collected data thematically and for content, as well as whether or not the mission statements and policy documents of the schools aligned with the principles of transformational leadership

Quantitative Analysis: The study summarized the responses of surveys through depicting the percentages of participants who observed improvements driven by leadership. Moreover, key metrics were compared based on the situation before after the leadership program implementation.

3.6 Ethical Considerations

Since consent is highly prioritized by the government of Uzbekistan, as well as considering the fact that some of the participants were minors, the author informed the subjects of the research on the purpose and procedures of the study. Additionally, all of the data collected was anonymized to ensure that the identities of the participants were fully protected. They were also notified that they could withdraw from the experiment at any time they wished so.

3.7 Validation and Reliability

The study combines the data from surveys, focus groups and interviews to ensure that findings are cross-validated and comprehensive, while also piloting survey instruments among small number set of schools so that reliability and clarity is provided. Through the combination of quantitative and qualitative methods, the research aims to provide actionable insights and to ensure sustainable improvements in educational institutions of Uzbekistan.

4. Results and Discussions

The following chapter illustrates the study's results while discussing the effects of recommended

[39] Global Partnership for Education. (2023). Government of Uzbekistan and development partners commit to education reforms in 2023–2026. GPE. – The National Partnership Compact defines measurable priorities for preschool and school education reform in Uzbekistan, with over $580 million committed for education support.

model of transformational leadership in enhancing the quality of education and learning environment in specialized schools of Uzbekistan. The author analyzed the findings against previous research, theoretical framework and practical realities of Uzbekistan's school leadership. The assessment was carried out on proposed transformational leadership model and on its ability to improve education quality, overall organizational environment and student performance.

4.1 Leadership Practices and Their Impact on Educational Quality

The findings showed that when transformational leaders were in charge of schools, there were significant improvement in curriculum delivery, teacher retention and student performance. Specifically, when leaders had collaborative visioning and involved all stakeholders in the development of a shared vision, the performance levels and student engagement were improved. In addition, when school leaders were open to invest in teacher training, instructional quality improved by 20%.[40] Moreover, when innovation was encouraged in teaching methods such as integration of technology and student-centered approaches, the school's posted enhanced learning outcomes.[41] The following findings prove the transformational leadership theory promoted by Bass, focusing on motivating and inspiring people towards collective goals.

4.2 Discussion

4.3.1 Impact on Quality of Education

The findings also concurred the hypothesis that leaders with transformational approach foster a learning environment that is positive, which inspired both students and teachers. In terms of emotional intelligence, when leaders possessed high levels of it, they were more effective in motivating the staff members and resolving any potential conflicts, in turn this improved performance and morale. In terms of empowerment, transformational leaders who empowered their teachers via participatory decision-making processes led to increased level of commitment and sense of ownership among staff towards quality education.[42] The results highlight how important it is to equip school principals with necessary skills to empower and inspire stakeholders that align with the findings of previous studies on educational leadership.

4.3.2 Accessibility Enhancement Strategies

It is no secret that not all students possess the same level of abilities and intellect, and it is important that the school leaders addressed accessibility challenges. Therefore, when school principals engaged with their communities for mobilizing resources such as providing the students with necessary educational tools, equipping the classrooms with latest technology, the outcome was significantly positive. In addition, principals also worked with local governments (khokimiyats) in funding resources for infrastructure development, which led to number of schools finding financial means of building stadiums and purchasing smart boards for classrooms.[43] The following tactics illustrated the school leaders' dual role of being change agents and educators, people who can address systemic inequities among schools.

4.3.3 Challenges in Model Implementation

While the proposed transformational model boasted number of strengths, the findings highlighted certain challenges in the implementation process. First, certain stakeholders were a bit skeptical and resisted the new initiatives, in particular, the integration of technology and changes to teaching methodologies. Some educators had over 10 years of experience and were quite successful in student performance, which is why they hesitated to take upon a new method that they were afraid would fail. As this proposed model was newly developed and had not gone through the proper testing phase, the study found that there were no structured training programs in place for school leaders, which became a barrier. Therefore, if these challenges had to be addressed, there need to be developed targeted interventions including stakeholder sensitization campaigns, increased funding by the government and training programs.

4.4.3 Comparison with Existing Models

To validate the study's findings, the author compared various leadership approaches against transformational leadership model including laissez-faire and transactional leadership approaches. In terms of laissez-faire, it proposes very minimal intervention that often resulted in poor outcomes and fragmented efforts in terms of accessibility. In terms of transactional leadership, it mainly focuses on keeping the status quo through punishing or rewarding employees, which led to decrease in fostering inclusivity and innovation. Meanwhile, innovative, inclusive and proactive nature of transformational model proved to be more effective in overcoming various challenges in Uzbekistan's education system.

4.5 Practice and Policy: Implications

Practical Implications

[40] Polatcan, M., Arslan, P., & Balci, A. (2023). The Mediating Role of Teacher Professional Learning in the Relationship between Transformational Leadership and Student Achievement. Education Sciences, 13(12), 1320. – This meta-analytic study found that all three types of leadership (instructional, transformational, distributed) affected teacher performance directly, and teacher performance had a direct effect on student achievement.

[41] Leithwood, K., & Sun, J. (2012). The Nature and Effects of Transformational School Leadership: A Meta-Analytic Review of Unpublished Research. Educational Administration Quarterly, 48(3), 387–423. – A comprehensive meta-analysis demonstrating that transformational school leadership has a substantial positive effect on school conditions and student achievement.

[42] Reyes, J. P. D. (2024). Transformational Leadership on Teacher Performance and Student Outcomes. Excellencia: International Multi-disciplinary Journal of Education, 2(12). – The findings confirm that leaders who inspire, intellectually stimulate, and provide individualized support to their teachers can create an atmosphere that enhances both teacher effectiveness and student performance.

[43] Ministry of Preschool and School Education of the Republic of Uzbekistan. (2023–2026). Education Reform Strategy. – Uzbekistan's education sector receives 20.5 percent of public expenditures and 4.9 percent of national GDP, with hundreds of modern schools including Presidential, specialized and creative schools established across all districts.

The study's practical implications hint towards capacity building, meaning that school principals should be provided with proper training in the principles of transformational leadership to ensure that the efficiency and effectiveness improve. Furthermore, the accessibility initiatives should be supported and funded by policymakers including digital platforms and learning tools. Last but not least, stakeholder collaboration is the key, and school leaders should be able to strengthen their partnerships with communities, parents and private sector members to ensure a sustainable impact.

Policy Recommendations

In terms of policy recommendations, there needs to be established a national leadership development framework to certify and train school principals in transformational leadership. Once incentive structures are developed and implemented, school leaders are more likely to focus on improvements in quality education and accessibility through transformational leadership. Later on, effective monitoring mechanisms should be put in place for tracking the effect of leadership practices on quality of education, student performance, teacher retention and overall learning environment.

5. Conclusion

In various sectors of the government and private sector, transformational leadership is viewed as an effective framework to address the obstacles in enhancing organizational performance. When school leaders foster a shared vision, while encouraging innovation and empowering teachers, this approach provides a meaningful and sustainable improvements in the education system. It should be noted that transformational leaders are important in communicating and defining a clear vision, which aligns with the objectives of all stakeholders, and this in turn ensures the processes that are focused on establishing impactful changes. The following leadership approach has the critical element of empowering the staff and teachers within the institution. When school leaders promote innovative culture, collaboration and professional development, their transformational leadership can improve teaching practices and learning environments, and this can improve the students' learning experience in the long-run. The following approach overcomes various socio-economic barriers, and helps leaders to ensure that all students have equal access to education. Moreover, transformational leaders often are able to engage with local communities and governments more efficiently, and involve external stakeholders and parents in fostering shared responsibility for the well-being of the children. Instead of basing their decisions on speculations or feelings, transformational leaders often use data analysis to evaluate the performance of the students and develop targeted interventions with their team members, continuously improving school strategies to achieve the overall objectives.

In order to equip school leaders of Uzbekistan with proper skills and knowledge, the local authorities and policymakers should invest in leadership training of these individuals. Furthermore, the strategies should be continuously assessed and adapted in order to better respond to emerging trends in the world market and economy.

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EFFECTIVE STORYTELLING IN TEACHERS' CONTEXT

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Abstract

This article examines storytelling as an effective instructional strategy in the context of primary education, with a particular focus on teaching English to young learners. It conceptualizes storytelling as an authentic form of communication and a carrier of cultural knowledge that supports both language acquisition and cognitive development. Drawing on relevant pedagogical literature, the study outlines key criteria for selecting appropriate stories and emphasizes the importance of systematic preparation, including the use of theatrics, props, scripting, and rehearsal. Furthermore, it proposes a structured framework of pre-, during-, and post-storytelling activities designed to enhance learner engagement, comprehension, and interaction. The article argues that storytelling facilitates the development of critical thinking skills, promotes cultural awareness, and supports integrated language learning. It concludes that, when effectively implemented, storytelling serves as a powerful and versatile tool for fostering meaningful and engaging language learning experiences in the primary classroom.

Keywords: storytelling; primary education; English language teaching (ELT); young learners; language acquisition; critical thinking; cultural transmission; classroom pedagogy; learner engagement; instructional strategies.

Introduction. Storytelling is an authentic form of communication that is a part of every culture. There are many people who are famous for crafting tales, and we still read their stories today. The legendary Aesop of Ancient Greece is probably one of the most famous storytellers; his fables are still told to children to teach moral lessons.

In many cultures, storytelling is also a tradition used to communicate culture from one generation to another to the next. For example, the elder Pueblo Indians in New Mexico pass down their culture and values to the younger generation through songs and stories. Children are actively involved with the storytelling and genuinely enjoy this traditional form of communication between generations.

In fact, many schools often use storybooks and storytelling as part of an elementary (primary) school curriculum because stories teach valuable lessons and literacy to children while also entertaining them. As Pinter A. mentions, "Listening to stories is the most authentic and popular activity for children, and primary English teachers can use storytelling as additional listening practice. Children will learn new language as well as having enjoyable listening practice. Language is picked up easily because stories contain repetition which makes linguistic input more noticeable" [4, 52-53].

Stories are a carrier of culture. As Curtain H. and Dalhberg C. state, "Story or narrative, is a powerful vehicle for experiencing culture. Values and concepts of the culture that are embedded in myths and folktales can be shared through storytelling, story reading, and dramatisation" [3, 266]. Well-written stories can capture the interest and imagination of children over multiple generations. Such stories ignite learners' curiosity and creativity while challenging them to learn new language or understand language in a new context. They particularly cater to young learners who have short attention spans and learn best through play and entertainment. When done effectively, storytelling is an enjoyable activity in which the language learning process is undetectable to children. As Slatterly M. and Willis J. point out, "Young learners acquire language unconsciously. The activities you do in class should help this kind of acquisition. Stories are the most valuable resource you have. They offer children a world of supported meaning that they can relate to" [5, 98].

Storytelling lends itself to helping students of all levels develop critical thinking skills - "the ability to analyse facts, generate and organise ideas, defend opinions, make comparisons, draw inferences, evaluate arguments, and solve problems" [2, 6]. These are important for students to develop in a primary school curriculum because they help students gain a deeper understanding of texts, including those that provide information from variety of cultures. Teachers can help students develop critical thinking skills by asking questions that require students to analyse and make inferences and by encouraging students to compare themselves and their cultures to the stories they have heard. Through this process, students can be encouraged to form their own opinions and evaluate a story for both content and delivery. When teachers encourage students to retell a story, they must also "summarise, edit and develop" the story, not just repeat the story word for word [6, 7]. Young learners also develop the ability

to sift through new stories and cultural information through a process of critical reflective thinking.

Storytelling is an art or a skill that can be developed. As you develop your storytelling skills, consider the following criteria that provide an effective storytelling experience for young learners.

Stories should: be highly predictable, be familiar to the home culture, have a high percentage of known vocabulary, include repetitive and predictable patterns, provide opportunities to apply drama and Total Physical Response (TPR), lend themselves well to use of visuals and realia to make input comprehensible [3, 8]. If stories meet these criteria, then it is possible to present an engaging storytelling experience that will keep young learners' attention and allow them to follow along in English without using their native language.

Once you have chosen the right story, the next step is to prepare to tell the story effectively. As Brewster J., Ellis G. and Girard D. point out, "…simply reading a story aloud to a class without preparation could be disastrous, with a loss of pupil attention, motivation and self-confidence. Pupils' enjoyment will increase enormously if we ensure their understanding is supported in several ways. Pupils will also need to feel involved and relate the story to aspects of their own experience" [1, 192]. Some teachers feel anxiety over storytelling because they fell that they have no natural talent for it, or they lack confidence in their own English language skills. However, with thoughtful preparation and practice, all teachers can create a successful storytelling experience for their students.

To make your storytelling engaging, prepare these four elements: Theatrics, Props, Script, and Rehearsals.

Aim to include aspects of these four elements in every storytelling session. If this is a new concept, start small and build up your skills slowly. As you gain confidence using one aspect, add another to your repertoire. The theatrics and props are particularly important as they help to generate interest and enjoyment in learners, and make input comprehensible.

Consider the story of Cinderella.

Theatrics	Props
Gestures	Visuals for setting and characters
Body movement	Realia
Dramatic pauses	Masks for role play
Character voices	Costumes for role play
Facial expressions	Hand or finger puppets
Speaking slowly and clearly	PowerPoint slides or storyboards

STORYTELLING PREPARATION

Rehearsals	Script
Memorise the text	Use illustrations from the storybook
Use cue cards if needed	Adapt the script to learners' level
Practice in front of the mirror	Create roles students can play
Record/videotape yourself	Integrate songs or chants
Rehearse using props	Prepare places for questions and predictions
Practice, practice, practice!	

Children love to hear stories told with different character voices, so you could use a young girl's voice for Cinderella; a rough, rude voice for her stepmother, unpleasant voices of her stepsisters, etc. In addition, you could use hand puppets and a drawing of the Cinderella's house on a poster or in a PowerPoint presentation along with the character voices. The combination of voices, puppets and the background drawing would make the storytelling fun and entertaining and would also help students understand the story better. Use a variety of theatrics and props to keep each storytelling fresh and new for learners.

Another storytelling element to consider is the script, which should be carefully prepared to be just above the learners' level of English and incorporate both new and known vocabulary and grammatical structures. Furthermore, script preparation should also build in time for student participation and comprehension questions throughout the storytelling, which will help keep the level of student engagement high. Children can role-play with the script by playing the character parts in Theatre's activities. The script can be simplified to adjust to the learners' level.

Finally, it is vitally important to rehearse the storytelling before the class. Although it is best to memorise as much of the text as possible, it can be helpful to prepare cue cards (cards with key words and plot elements from the script) to help guide your performance.

In order to design effective storytelling activities, it is important for teachers to think about activities before, during and after the storytelling. In addition to the preparation for making the story come alive, the teacher needs to prepare students with the language to understand the storytelling before. Activities to keep students active and engaged in class at every step of the storytelling should also be planned [7].

I. Activities before Storytelling.

Such activities are done to aid comprehension, create interest and enjoyment, make the storytelling more meaningful and encourage critical thinking.

Capture students' attention: use pictures to introduce the story in a fun and interesting way or you can create fun visuals. To make the characters come alive, the teacher can make stick puppets of the characters and introduce them to the class. To draw students into the scenery of the story, the teacher can make a background on poster paper and put it up on the classroom wall or project the scenes from the laptop onto the wall. For example, for the story 'The Rainbow Fish' the teacher may use an underwater scene from the book and brightly-coloured puppets of the fish and a multicoloured Rainbow Fish with shiny silver scales.

Connect to prior knowledge and experience: it is important to connect students' lives to the story. This includes introducing the main ideas, concepts or characters to students. For example, if the story is 'Goldilocks and the Three Bears', the teacher may prepare students by introducing the concepts of family since the story's main characters are Goldilocks, Baby Bear, Mama bear, Papa Bear. The teacher can also ask students about their own country or culture's since many countries have similar fairytales or folktales.

Review language students have learned: The review of language is often related to background knowledge and students' experiences.

For example, to repeat grammar structures and vocabulary, large thematic units, etc. 'The Very Hungry Caterpillar' has vocabulary for food, numbers, days of week and the life cycle of a butterfly, so the teacher may connect students' background knowledge of food with the concepts of food, numbers, etc.

Pre-teach new vocabulary and expressions: If there are key words or structures that are necessary to comprehend the story and cannot be inferred from the context, it is better to teach them before the storytelling. The teacher can capture attention, introduce the context, review known words, and then pre-teach vocabulary.

Ask students to predict what will happen in the story: It can be helpful to encourage students to predict what will happen in the story. Prediction is a good critical thinking skill to encourage students. Be sure to record their thoughts to check whether they are correct later. Students can write one sentence they think will be in the story and put it in a prediction box. Then at the end of the story, the teacher can read the sentences out loud for fun. To lower level students, the teacher can write some sentences on the board, and ask students to choose the ending by writing one of them. For example, for Aesop's fable about the Lion and the Mouse, the teacher can give these sentences for students to choose and write: 'The Lion eats the mouse. The mouse saves the lion. The lion saves the mouse.'

Making a prediction helps students pay attention to the story and think critically to check their predictions during the storytelling.

Give students a purpose for listening: Before telling the story, give students a purpose for listening, so this can help them stay engaged and make them more active listeners during the storytelling (for example, to repeat sounds, songs, chants, lines from the story, etc).

II. Activities during Storytelling.

During storytelling activities are usually used to check comprehension. They can also be used to keep students' interest and allow them the chance to interact and practice using English.

Q & A: the teacher should keep a balance between asking questions (like, about the characters, setting, and plot) to keep the learners engaged. For example, if he is telling the Aesop's fable 'The Hare and the Tortoise' it could progress like this: "A hare is also called a …" (rabbit); "A tortoise is also called a …" (turtle); "What is Hare doing?" (hopping fast); "is Tortoise sleeping too?"

Repetition: repetition of key phrases or chants in a story can keep students active and give them a chance to practice set phrases or language structures.

TPR (Total Physical Response): movements and actions can be built into the most students' stories. Doing TPR with students during the storytelling appeals to kinaesthetic learners and makes the experience more active and fun [8]. This is also supports comprehension of the story and the teacher should look for movement to accompany a storytelling.

Create your own ending: Teachers can tell the story up to the climax asks students to predict the ending before they finish telling the story.

Keep ask students to predict in Warm-up.

III. Activities after Storytelling.

After a storytelling, you can do follow-up activities to check comprehension of the story. Post-storytelling activities should also give learners plenty of practice using the new language structures and vocabulary. Try to use four language skills, cooperative activities, scaffolded instruction and activities that cater to different learning styles and intelligences.

Check predictions: check the predictions that students made in the before- or during-storytelling stages.

Group retelling may include role-play; students can act out the story, etc.

Games: try the game 'Start and Stop', where you can retell the story with mistakes and have students stop you when they hear a mistake.

Story analysis: Students can show their deeper levels of comprehension of the story by analysing the characters, ending or moral of a story and plot.

Personalised story: Have student write a story similar to the one in the storytelling but with details that

draw from their own experiences, culture and imagination.

Projects: Have students work together in small groups to complete a project that shows comprehension of a story. The project can be a part of a thematic unit requiring students to learn more about the story topic, context, author, culture, etc. Student can also research information about the author.

Play performance.

Conclusions. Storytelling is a fun, exciting way to present English in a meaningful context and expose students to their culture. It is also an authentic form of communication. Storytelling can help teachers incorporate the development of critical thinking skills and deepen their understanding of how stories are connected to their lives and culture.

Since storytellers are performers, teachers can be ready to prepare their theatrics, props, script and rehearse before performing.

Good storytelling involves preparing before-, during-, and after-storytelling activities. These activities capture students' attention and encourage them to practice the language.

Moreover, storytelling can promote thematic learning that develops the four language skills in an integrated period of time.

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SOCIAL ASPECTS OF LEARNING DISABILITIES IN SCHOOL EDUCATION

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Abstract

This study examines the social dimensions of learning disabilities within school education. It aims to identify key social factors that shape the academic experiences of students with learning disabilities, including family environment, school climate, teacher attitudes, and peer relationships. Drawing on both quantitative and qualitative data collected from teachers and students, the study finds that social factors exert a considerable influence on academic performance, motivation, and engagement. In particular, supportive teacher-student relationships and inclusive classroom environments are associated with improved student outcomes. Conversely, limited awareness, insufficient resources, and inadequate parental involvement emerged as significant barriers. The study underscores the need to address social dimensions alongside pedagogical strategies to strengthen inclusive education practices. The findings may be of value to educators, school administrators, and policymakers engaged in supporting students with learning disabilities.

Keywords: learning disabilities, social factors, inclusive education, school environment, teacher attitudes

Introduction

Inclusive education has become one of the defining priorities of contemporary educational systems. Within this context, growing attention is being directed toward students with learning disabilities, who frequently encounter a range of challenges throughout the learning process. These challenges extend beyond cognitive difficulties and are substantially shaped by the social environments in which students learn.

The social environment plays a central role in determining students' academic experiences. Family support, teacher attitudes, peer relationships, and the overall school climate can significantly affect motivation, engagement, and academic achievement. For students with learning disabilities, these factors are particularly consequential, as they may either facilitate or impede successful integration into educational life [8].

This study aims to examine the social aspects of learning disabilities in school education and to identify the key factors influencing students' academic experiences. The study also seeks to illuminate existing challenges within educational environments and to offer insights for improving inclusive practices [1].

Theoretical Background

Learning disabilities are defined as neurodevelopmental conditions that affect the acquisition and application of academic skills such as reading, writing, and mathematics [6; 7]. These difficulties are not attributable to intellectual impairment but arise from differences in how individuals process information [1]. Students with learning disabilities typically require targeted support and adapted instructional approaches in order to reach their full academic potential.

In recent years, considerable attention has been devoted to the role of social factors in the educational experiences of these students. Research indicates that family involvement, teacher expectations, and peer interactions exert a strong influence on academic development and emotional well-being [5]. A supportive environment can foster motivation and self-confidence, whereas negative attitudes and a lack of support may contribute to disengagement and academic underperformance [4].

Inclusive education emphasizes the importance of developing learning environments that are responsive to the diverse needs of all students. In this regard, it is essential to consider not only instructional strategies but also the broader social conditions that frame the learning experience. A deeper understanding of these factors enables educators to more effectively support students with learning disabilities and to advance inclusive educational practices [2; 3].

Methodology

The study employs a mixed-methods research design, combining quantitative and qualitative approaches to obtain a comprehensive understanding of the subject. Data were collected through structured questionnaires and semi-structured interviews.

The target population comprised school teachers, administrators, and specialists working with students with learning disabilities. Participants were selected through stratified sampling based on geographical distribution across several regions of Georgia.

Quantitative data were gathered via structured questionnaires, while qualitative data were obtained through in-depth interviews. The data were subsequently analysed using descriptive analysis methods, enabling the identification of key patterns and trends relating to the role of social factors in the educational experiences of students with learning disabilities.

Ethical standards were observed throughout the research process. Participation was voluntary, and the confidentiality of all respondents was ensured.

Results

The findings indicate that social factors play a substantial role in shaping the educational experiences of students with learning disabilities. The majority of

teachers demonstrated positive attitudes toward inclusive education and acknowledged the significance of social support in the learning process.

65% of respondents reported a general familiarity with learning disabilities, while a smaller proportion indicated more in-depth knowledge. At the same time, over 80% of participants expressed favorable attitudes toward inclusive practices, although many noted the need for additional professional training and material resources.

Teacher-student relationships were identified as one of the most influential factors affecting students' motivation and classroom participation. Supportive communication and consistent encouragement were associated with higher levels of engagement, while limited awareness and insufficient support were identified as barriers to effective learning.

The study further revealed that peer relationships and classroom climate have a considerable impact on students' academic performance and emotional well-being. Inclusive and supportive environments were shown to promote better social integration and increased confidence among students with learning disabilities.

Discussion

The findings of this study confirm that social factors are integral to the academic development of students with learning disabilities. Positive teacher attitudes and inclusive classroom environments were found to contribute meaningfully to students' motivation, engagement, and overall outcomes - a finding that is consistent with the broader literature on inclusive education [2].

At the same time, the study identifies several persistent challenges affecting the implementation of inclusive education. Limited resources, insufficient professional development opportunities, and a lack of awareness among school staff remain significant obstacles. These findings align with existing research emphasizing the importance of both pedagogical and social support in inclusive settings [2].

The results also suggest that strengthening collaboration among teachers, parents, and school administrators can enhance the effectiveness of inclusive practices. Establishing robust communication channels and providing adequate support systems may lead to measurably better educational outcomes for students with learning disabilities.

Conclusion

This study demonstrates that social factors play a decisive role in the educational experiences of students with learning disabilities. Supportive teacher attitudes, positive classroom environments, and effective communication are each associated with improved motivation and academic outcomes.

At the same time, the research highlights a number of unresolved challenges, including limited resources, inadequate training opportunities, and insufficient awareness among educational practitioners. Addressing these issues is essential for the effective implementation of inclusive education.

The findings underscore the importance of strengthening social support systems within schools to create more inclusive, equitable, and effective learning environments for all students.

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A PRACTICAL ENTRY STRATEGY FOR LEARNING ANALYTICS IN MATHEMATICS COURSES AT A TECHNICAL UNIVERSITY

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Abstract

This short article proposes a compact strategy for introducing learning analytics into mathematics teaching at a technical university. The paper is based on the broader discussion developed in the authors' longer conceptual work, and builds on the Project 101082889 MEDIA, which focuses on establishing Inter-University MEDIA Centers to advance the modernization and internationalization of online education systems and contribute to strengthening regulatory frameworks, implementing Learning Analytics, and developing accredited multidisciplinary digital media programmes aligned with EU best practices and evolving labour market demands shaped by the post-COVID context [19]. Nevertheless, it is intentionally reframed as a smaller and more practice-oriented contribution rather than presenting a full institutional framework. The article focuses on a limited pilot pathway that begins with one or two mathematics courses in Moodle and develops from simple platform reports toward modest exploratory analysis. The argument is that mathematics offers an especially suitable entry point because its topic progression is explicit, learning bottlenecks are recurrent, and digital traces can often be interpreted pedagogically with less ambiguity than in more open-ended disciplines. The paper outlines a four-step adoption model, identifies feasible analytical indicators for pilot courses, and discusses basic methodological, ethical and organizational conditions for implementation. Its contribution lies in showing how a technical university with uneven digital maturity can start small, build methodological confidence, and prepare for later institutional scaling without treating learning analytics as a purely technological project.

Keywords: Media, digital education, learning analytics; mathematics education; Moodle; pilot implementation; technical university; higher education

1. Introduction

Digital teaching environments continuously generate traces of student activity. Resource views, quiz attempts, submission times, forum messages, and repeated visits to difficult content create a behavioral record that can potentially support more informed teaching decisions. The field of learning analytics emerged precisely from the idea that such traces should not remain unused, and early foundational work already argued that educational data could improve understanding of learner behavior and institutional practice [1, 2]. Subsequent discussions emphasized that analytics is meaningful only when it remains connected to pedagogy rather than being treated as a technical reporting exercise [3, 4].

At the same time, the literature has shown that many universities are data-rich but interpretation-poor. They often have learning management systems and access logs, yet lack practical routines for connecting those data with course design, assessment structure, and feedback practices [5, 6]. Reviews of empirical work in educational data mining and learning analytics suggest that methodological sophistication alone does not guarantee pedagogical value [7, 8]. More recent studies on institutional adoption have reached a similar conclusion: successful implementation depends on operational infrastructure, regulatory framework, strategy, stakeholder alignment, staff readiness, and careful local adaptation [9, 10, 11, 19].

This article addresses that practical gap in a deliberately modest way. Instead of presenting a large institutional roadmap, it proposes a short entry strategy for one limited domain: mathematics courses at a technical university. The choice is intentional. Mathematics courses typically have visible topic dependency, repeated formative checkpoints, and stable patterns of conceptual difficulty. These characteristics make them a promising starting point for small-scale learning analytics, especially in universities where digital maturity remains uneven across departments. The paper therefore asks a narrower question: how can a university begin with a realistic, low-risk pilot that supports teaching improvement without producing a second full-length theoretical framework?

2. Why a Smaller and More Focused Pilot Paper?

The present text is intentionally different in scope and genre from a full conceptual-methodological article. Its purpose is not to review the whole field or to formulate a complete institutional framework. Instead, it concentrates on an actionable pilot logic that could be communicated in a shorter journal format. This shift is important not only for publication strategy but also for methodological clarity. A compact paper can be stronger when it does fewer things but does them explicitly.

This more limited framing is also consistent with current discussions in the literature. Institutional frameworks such as SHEILA have shown the importance of policy, stakeholder coordination, and implementation planning [12], the role of learning analytics in online education [19] while ethics-oriented discussions have highlighted privacy, transparency, and responsible data use [13]. Research on teacher data literacy and data-based decision-making further demonstrates that implementation depends on the human capacity to interpret evidence, not only on the existence of dashboards

[14, 15]. A short pilot-oriented paper should therefore avoid overstating institutional ambition and focus instead on a credible first step.

3. Why Mathematics Is an Effective Entry Point

Mathematics is especially suitable for an initial learning analytics pilot because it combines structured content progression with repeated evidence of student understanding. In courses such as linear algebra, probability theory, and introductory statistics, later success typically depends on earlier conceptual mastery. When a student repeatedly fails one topic, that difficulty often propagates forward in a visible way. This makes activity traces easier to interpret pedagogically than in many broader or more discursive subjects.

Another advantage is that mathematics produces both quantitative and qualitative evidence. The quantitative side includes quiz attempts, completion patterns, response timing, and grade distributions. The qualitative side includes short explanations, forum questions, and written reasoning about solutions. Earlier work on online participation has shown that interaction can also be studied relationally, for example through social network analysis of discussion structures [16, 17]. Likewise, text-oriented analytics may help identify recurring misunderstandings when students explain concepts or justify answers [18]. In mathematics, these different forms of evidence can often be linked to clearly defined curricular transitions, which makes a pilot analytically manageable.

4. A Four-Step Entry Strategy

A practical pilot does not need to begin with predictive modeling or advanced automation. A more realistic starting point is a sequence of four manageable steps. The first step is a digital course check. One or two mathematics courses should be reviewed in Moodle in order to determine whether they already contain clearly separated topics, traceable student pathways, regular assessments, and exportable activity data. If the course architecture is inconsistent, analytics will remain noisy and difficult to interpret.

The second step is minimum pedagogical redesign. The aim is not to rebuild the course from scratch, but to make the digital structure legible. Topics should be organized in a clear sequence, activity completion should be enabled where appropriate, and assessment points should correspond to the logic of the syllabus. This is where the literature on analytics and feedback becomes especially relevant: useful data emerge from meaningful pedagogical design rather than from raw logging alone [6, 9].

The third step is the use of built-in Moodle reports. At this stage, teachers can already identify topic-level drop-off points, unusual patterns of incomplete progression, and gaps between participation and achievement. Even simple platform reports may reveal where students stop following the intended learning path or where repeated task failure clusters around a specific concept. For a short pilot, such evidence is often sufficient to motivate targeted instructional adjustment.

The fourth step is modest exploratory analysis of exported logs. After the first descriptive observations, a small dataset can be exported from Moodle and examined in Python or another accessible environment. The goal is not to build a high-stakes prediction system. Instead, the analysis should look for interpretable patterns: repeated unsuccessful attempts, late bursts of activity before assessments, long gaps between topic visits, or the absence of resource consultation before quiz retakes. These simple indicators may help teachers distinguish between weak engagement, procedural trial-and-error, and concept-specific struggle.

5. Illustrative Indicators for Pilot Courses

For a short pilot, a compact set of indicators is preferable to a large dashboard. Three types of indicators are especially useful. The first are progression indicators: section completion, order of topic access, and continuity of course navigation. These help determine whether students follow the designed learning path or fragment their participation. The second are performance-process indicators: number of attempts, time between attempts, and variation between early and later quiz results. These can suggest whether improvement is occurring through learning or merely through repetition.

The third are communication indicators. Even in courses that are not heavily discussion-based, forum activity, consultation requests, and short textual answers may reveal where conceptual uncertainty accumulates. If interaction data are available, a teacher can observe whether only a small number of students dominate course communication or whether questions remain isolated and unanswered. This makes social participation visible in ways that ordinary gradebooks do not [16, 17]. If short open responses are collected, even basic text grouping can highlight common forms of misunderstanding [18].

6. Practical Use Scenarios in Mathematics Courses

A compact article benefits from concrete examples. In a linear algebra course, the pilot may focus on the transition from procedural manipulation to abstract concepts such as basis, dimension, and linear independence. Here, analytics can reveal whether students repeatedly succeed in routine calculations but disengage or fail when symbolic or conceptual tasks appear. In probability theory, the emphasis may shift toward the gap between formal formula application and conceptual interpretation. Students sometimes produce numerically correct answers while misunderstanding independence, conditionality, or distributional assumptions. In introductory statistics, teachers may observe whether students can compute descriptive measures but struggle with interpretation, uncertainty, or the meaning of inferential results.

These examples matter because they connect digital traces with discipline-specific teaching questions. A log file by itself does not explain why a concept is difficult, but a well-designed course allows the teacher to interpret the traces in relation to a known curricular bottleneck. That is one reason mathematics is such a suitable entry domain. The course structure is usually explicit, the transitions between topics are clearer than in many open-ended disciplines, and recurring misconceptions are often stable across cohorts. For a technical university, this means that the first pilot can remain small while still being pedagogically meaningful.

A further advantage is that the results of such a pilot can be discussed directly with instructors in practical terms. Instead of speaking in abstract institutional language, the conversation can focus on identifiable course moments: a topic where many students stop reviewing materials, a quiz that generates repeated retakes without improvement, or a concept that triggers a spike in forum questions. This supports a more credible adoption process, because the value of analytics is demonstrated in relation to real teaching problems rather than software features.

7. Institutional and Ethical Conditions

A small pilot still requires basic institutional discipline. First, students should be informed that course platforms record activity and that such records may be used for teaching improvement. Second, only data that are pedagogically relevant should be examined. Third, any exported or shared dataset should be anonymized or pseudonymized before analysis. These principles are widely consistent with ethical discussions in learning analytics and remain essential even for a modest exploratory study [13].

Faculty support is equally important. The literature on adoption repeatedly shows that strategy fails when staff members are expected to use analytics without interpretive support or without a clear understanding of why the data matter [10, 11, 14, 15]. In practical terms, this means that a pilot should be accompanied by short methodological consultations rather than by technological deployment alone. A teacher needs help answering concrete pedagogical questions, not simply access to a platform report.

8. Discussion

The main argument of this article is that universities do not need to begin learning analytics with a large institutional system. In many cases, especially in technically strong but digitally uneven institutions, it is wiser to start with a narrow pilot that creates methodological confidence. This position aligns with the broader literature, which increasingly treats learning analytics as part of a higher education ecosystem rather than as an isolated software layer [11]. It also responds to a common implementation problem: institutional rhetoric often advances faster than course-level practice.

A mathematics-centered pilot offers a useful compromise between ambition and feasibility. It provides enough structure for data interpretation while remaining close to real teaching problems such as recurring misconceptions, fragmented participation, and unstable preparation for assessments. In this sense, the value of the pilot lies not in prediction accuracy or scale, but in the ability to generate teacher-usable evidence. That narrower claim is more appropriate for a short paper and more realistic for an early implementation stage.

9. Conclusion

This article has presented a compact and practice-oriented strategy for introducing learning analytics into mathematics courses at a technical university. Unlike a large conceptual framework, the paper focuses on a small-scale pathway: review one or two Moodle courses, improve their pedagogical legibility, use built-in reports, and then conduct modest exploratory analysis of exported logs. The proposed approach is intentionally limited, but that limitation is also its strength. It offers a manageable starting point for institutions that want to connect digital traces with teaching decisions without overstating technical or institutional readiness.

The broader implication is simple. Learning analytics becomes meaningful when it begins with a well-structured course, a concrete pedagogical question, and a realistic interpretation of available evidence. Mathematics provides a suitable entry point for this work, and a compact pilot can prepare the ground for later, more systematic development.

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PHILOLOGICAL SCIENCES

CONCEPTS AND MODELS OF DISCOURSE IN THE CONTEXT OF LINGUISTICS

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Abstract

This article examines the concepts and models of discourse in the context of linguistics. In modern linguistics, the study of discourse, its various approaches and types, is widespread. Although discourse has been studied from semiotic, semantic, pragmatic, cognitive, and other perspectives in the works of both Western and Russian scholars, a number of questions pertaining to discourse remain unresolved in linguistic science. As a linguistic category, discourse is closely related to sociology, psychology, philosophy, and history, and is accordingly characterised as a category that penetrates many fields of scientific inquiry. The article analyses linguistic and extralinguistic factors as criteria for defining discourse as a linguistic term, reviews prominent theoretical perspectives advanced by scholars of the French, German, and Russian linguistic schools, and considers the place of discourse research in Azerbaijani linguistics. The main features and classification models of discourse are investigated, and conclusions regarding its communicative, cognitive, and social dimensions are drawn.

Аннотация

В данной статье рассматриваются понятия и модели дискурса в контексте лингвистики. В современной лингвистике широко распространено изучение дискурса, различных подходов к нему и его видов. Хотя это явление изучалось в семиотическом, семантическом, прагматическом, когнитивном и других аспектах в трудах как западных, так и отечественных исследователей, в лингвистике до сих пор существуют нерешённые вопросы, связанные с дискурсом. Как лингвистическая категория, дискурс тесно связан с социологией, психологией, философией и историей, в связи с чем характеризуется как категория, пронизывающая многие области научного знания. В статье анализируются лингвистические и экстралингвистические факторы как критерии определения дискурса в качестве лингвистического термина, рассматриваются теоретические концепции учёных французской, немецкой и российской лингвистических школ, а также место дискурсивных исследований в азербайджанском языкознании.

Keywords: discourse, linguistic category, discourse theory, style, communication, lexical units, characteristics of discourse, speech

Ключевые слова: дискурс, лингвистическая категория, теория дискурса, стиль, коммуникация, лексические единицы, характеристики дискурса, речь

1. INTRODUCTION

In modern linguistics the study of discourse is conducted across a very broad spectrum of inquiry. As a linguistic category, discourse is closely related to such scientific fields as sociology, psychology, philosophy, and history. Consequently, it is characterised as a linguistic category that penetrates many areas of scientific knowledge, each of which has its own methods for approaching objects of research.

For this reason, the definitions attributed to discourse as a specific domain of scientific investigation are not limited to linguistics but extend beyond its boundaries. Even among linguists, discourse is assigned various definitions. What unifies these definitions, however, is an interest in the structure of language, its functionality in speech activity, and the role of the human factor in communication. Language performs an important sociological function in relation to society: members of a community communicate and understand one another through language. In this process, the delivery of information, communicative influence, and the linguistic foundations of speech construction constitute central problems of contemporary linguistics.

The present article is devoted to the examination of the main concepts and models of discourse as they have been developed within the framework of linguistics. Its objective is to review the theoretical positions of leading scholars, to analyse the defining criteria of discourse as a linguistic term, and to outline the key features and classification principles that have been proposed in the literature.

2. THEORETICAL BACKGROUND AND MAIN SCHOOLS OF DISCOURSE STUDY

Discourse as a field of linguistic study began to gain wide currency in the second half of the twentieth century. The anthropocentric paradigm associated with Émile Benveniste made it possible to penetrate the deeper dimensions of discourse study, and the investigation of this problem from the perspective of cognitive linguistics led to the formation of discourse theory and its development on new scientific foundations.

Among the founders of the structural-linguistic approach to discourse, the contributions of E. Benveniste and M. Pêcheux are of particular importance. Benveniste characterises discourse as a large and complex linguistic structure and understands the term to encompass not only a language structure based on a system of signs, but also procedural, communicative features. In

his view, the world of language is the world of discourse as a means of communication [1].

Pêcheux proposes the concept that in discursive analysis, language and ideology converge, and that the meaning of words changes according to ideological position. In his view, the discursive process expresses ideological relations. His concept of discourse exerted a strong influence on the development of the French school of discourse analysis.

In the German tradition, philosopher Jürgen Habermas occupies a unique position in discursive analysis. He accepts discourse as a social activity, and attributes particular significance to the dramatic character, normativity, communicativeness, and social legitimacy of discourse in his research.

Michel Foucault, a leading representative of the French linguistic school, advanced a cartological analysis of discourse. The French structuralist concept based on Foucault links discourse with the correlation of speech practice and human mental constructions. From this perspective, discourse may be characterised as a particular way of perceiving the world that is realised in speech. Foucault's discourse is understood as a set of statements characteristic of a particular historical period, operating according to a certain set of rules [2].

Teun A. van Dijk, whose work synthesises diverse approaches to discourse, proposes that discourse be understood as a communicative phenomenon and as "a complex unity of language form, meaning, and action" [3]. The advantage of this concept, as van Dijk notes, lies in the fact that discourse is not confined to a specific linguistic frame of expression — whether the text or the dialogue itself — which resists purely intuitive or exclusively linguistic approaches to its definition. At the same time, van Dijk does not reject the interpretation of discourse as a sequence of consecutive sentences, that is, as text and speech.

P. Sériot, a representative of the French discourse school, enumerates eight distinct meanings of the term, reflecting its breadth of usage: (1) as a synonym for speech in the Saussurean sense; (2) as a phrasal unit, the object of text grammar; (3) from a pragmatic standpoint, as referring to the impact of speech and situation upon the recipient; (4) as a particular type of utterance, specifically narrative utterance; (5) in the Benvenistean sense, as speech produced by a speaker; (6) as a concept in opposition to speech; (7) as a special type of speech; and (8) as a concept distinguished from speech, with its own object of study.

3. COGNITIVE AND CRITICAL DISCOURSE APPROACHES

V.V. Krasnykh, a prominent representative of the Russian discourse school, draws on van Dijk's concept to interpret discourse in both a narrow and a broad sense. In the narrow sense, it refers to ordinary, everyday speech; in the broad sense, it refers to the potential speech creation of a language object understood as a communication system.

V.A. Koch draws attention to the motivated nature of all text. He argues that any text contains a motive, which he proposes to call a discursive text. This position represents a logical-semantic approach to discourse, and has been accepted by many specialists. The term "motive" in this context implies dynamic narration as well as a stable theme or idea of the text.

The method of critical discourse analysis (CDA), developed by Norman Fairclough, represents one of the outcomes of the multidisciplinary approach to discourse [2]. Fairclough identifies several interpretations of the concept. First, discourse is defined as a social linguistic phenomenon, with social effects analysis as the primary method. Second, discourse constitutes a type of language used in a particular field — such as political discourse. Third, discourse is understood as a mode of "speaking" that gives meaning to experience from a particular point of view. Fairclough identifies the formation of social identity, social relations, and systems of knowledge and meaning as the principal functions of discourse.

Depending on the criteria applied, scholars propose different classifications of discourse. J. Torfing identifies three types corresponding to three research traditions: discourse in the narrow linguistic sense, critical discourse analysis, and discourse in the poststructuralist sense.

V.I. Karasik distinguishes personal and institutional discourse. Personal discourse manifests itself in everyday communicative speech — where speakers share mutual understanding and the topic of conversation may change rapidly — and in existential speech — where ideas are expressed as clearly and structurally as possible. In both cases, speech activity is predicated on the active comprehension of content by the addressee. The comprehension of meaning in everyday speech depends on the specific situation of communication, whereas in existential discourse it depends on the form of the sign and the personal conceptual sphere of the addressee [4].

The most important criterion for institutional discourse is the social status of the speaker, since people's activities correspond in various ways to their discursive practices. Any area of socio-cultural activity may therefore be attributed to a particular discourse. In this context, the concepts of "discourse" and "style" converge. O.S. Akhmanova, in her Dictionary of Linguistic Terms, defines style as a subsystem of language that differs from other types primarily in the expressive-evaluative properties of its constituent elements, possessing its own vocabulary, phraseological combinations, expressions, and constructions, and associated with particular areas of speech use. Institutional discourse, like style, is characterised by the differentiation of linguistic elements according to the intensity of their use in a particular field of activity.

4. DISCOURSE RESEARCH IN AZERBAIJANI LINGUISTICS

In Azerbaijani linguistics, discourse occupies an important place in the research of scholars including F. Veysalli, A. Mammadov, M. Mammadov, A. Abdullayev, F. Jahangirov, and others. These scholars have engaged with the ideas of leading international discourse theorists and have advanced significant contributions of their own [7, 8].

Professor F. Veysalli has conducted extensive studies on discourse and discourse genres [8]. Professor

A. Mammadov, in his article "Modern Problems of Linguistics," characterises discourse as a piece of speech that is in action when confronted with a text: it acquires a certain meaning in context, and is used by the person conveying information for particular purposes, in specific circumstances and in a specific sense.

A. Abdullayev emphasises that the terms "text" and "discourse" are both widely employed in the study of coherent speech, and distinguishes two main tendencies in approaches to them. The existence of different relationships between text and discourse, and of divergent approaches to these concepts, constitutes a serious issue in the study of discourse.

F. Jahangirov characterises discourse as follows: an equal sign cannot be placed between discourse and text, because when considering discourse, attention must be focused not only on what is said but also on what is not said or cannot be said, yet which has its place in meaning. If discourse is taken as the unity of an already formed text and its context, its status as discourse becomes apparent only in the process of perception by another person or persons. Unactualised discourse is only potential discourse.

5. CONCLUSIONS

The foregoing analysis of the concepts and models of discourse in the context of linguistics yields the following conclusions.

First, discourse involves at least two parties — the speaker and the receiver, the addresser and the addressee. This means that discourse is not the property of a specific individual alone. It is cognition actualised and realised through certain means: in addition to linguistic means, non-linguistic means that create context in the broadest sense are also closely involved in this actualisation.

Second, in defining discourse, attention must be drawn to such important considerations as the principle of selection of language units, the actualisation of words related to the speaker's speech or their semantic shades, and the preservation of the ideological and social content of the utterance in the construction of the text. In general terms, the concept of discourse has been employed in linguistics in connection with speech, dialogue, style, and related phenomena.

Third, discursive knowledge, skills, and habits differ in their cultural specificity as a product of interpersonal relations; any discourse is constructed according to the laws of a specific language community. The language community is characterised by extralinguistic, socio-cultural knowledge, skills, and habits that collectively shape the parameters of communicative behaviour.

Fourth, the study of discourse requires a multidisciplinary perspective: its analysis cannot be confined to purely linguistic methods but must draw on insights from sociology, psychology, philosophy, and cognitive science. The synthesis of these perspectives is what enables a comprehensive account of discourse as both a linguistic and a social phenomenon.

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SIGNIFICANCE OF RELATIONS FOR TRANSLATION: -TAI ELEMENT IN $NP_1+P_{(-TAI)}+NP_2$ CONSTRUCTION OF MONGOLIAN INTO ENGLISH

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Abstract

The syntactic and semantically relevant grammatical relations (henceforth, the grammatical relation/s) of any linguistic elements play a crucial role in a language. As their representative, this study examines the grammatical relations of -TAI element focusing on its syntactic properties.

The -TAI is the second most active grammatical element in the Mongolian language as it functions as a suffix that derives adjectives from nouns, and a comitative case marker. Among the various elements requiring more analysis, the relational element -TAI in NP_1+P(-tai)+NP_2 construction in Mongolian, which is tended to be translated into other languages literally, was selected for its complexity and ambiguity, specifically in translation, aiming to determine the significance of the syntactic and grammatical relations of the corresponding element from a linguistic point of view for translation into English as a non-cognate language of Mongolian.

Upon analysing the given linguistic facts, it becomes evident that the -TAI element syntactically generates the $NP_1+P_{(-tai)}+NP_2$ construction through daughter relation between NP_1 and NP_2 and denotes a general grammatical relation 'a trace or result of an action that has already been performed'.

In conclusion, it is important to note that when the nouns in the NP_1 and NP_2 are replaced by each other or one another, the resulting construction remains structurally or syntactically identical but the grammatical relations of the -TAI in the construction is entirely changed into many, due to the distribution, lexical meaning, lexical entry and correlation of the nouns in the NP_1 and NP_2 in Mongolian that is a representative of all human languages universally.

Keywords: $NP_1+P_{(-tai)}+NP_2$ construction, -TAI (relational) element, (semantically relevant) grammatical relations, I/E-structure, sister/daughter relation

1. Introduction

Mongolian, a language of the Altaic family, possesses an SOV (agglutinative) structure characterized by numerous verb syntagms, rendering the NP_1+P+NP_2 construction rather uncommon. In the context of Mongolian, this construction is predominantly generated by a relational element -IIN/-NII, alongside others: -TAI[44], -SHIG, MET, ADIL, -NII TUKHAI, -NII GADNAKH, -NII ÖMNÖKH which we have categorized as OTHER[45] in our studies. The elements in the latter category are significantly fewer in number compared to the former. Through this study, we focus on the -TAI element as mostly contributing to generate this $NP_1+P_{(-tai)}+NP_2$ construction rather than other elements in this categorization OTHER which are adjuncts in the verb phrases (VPs).

First, our literature analysis has revealed a significant gap in this subject that requires further investigation. Second, translating is the process of converting one sign from one language into another. Although it appears to occur in the E-structure, it is, in fact, a process that is naturally performed in the E-structure via the I-structure. Conversely, the translation is commonly done in a literal way relying on the I-structure of any elements in the source language. One representative is the $NP_1+P_{(-tai)}+NP_2$ construction specifically generated by the -TAI element in Mongolian which is translated into English using morphological, lexicological and syntactic methods; however, the specific contexts for employing each method remain ambiguous. An example *nom**toi** khün* in Mongolian can be translated into English in three distinct alternatives (1-3) at least.

(1) *A person who has collected numbers of books or sutras*

(2) *A scholarly person* / *A person who is well-educated*

(3) *A person who is erudite and proficient in the best way of life according to the natural laws*

This is a big question about such methods or techniques which inevitably attracts more interests from language learners, teachers and researchers.

The major response to this question pertains directly to the I-structure or initial-structure of the $NP_1+P_{(-tai)}+NP_2$ construction. Definitely, it is inappropriate to investigate the grammatical relations of the -TAI element which holds a distinctive role in the construction of Mongolian, exclusively through this element, due to the fact that this element connects NP_1 and

[44] Orthographically, the -TAI element has two alternatives in old Mongolian script: -TAI and -TEI; but three: -TAI, -TEI and -TOI in Cyrillic.

[45] We use this capital form 'OTHER' as the term of the classification, but the lowercase form 'other' as a general word in our studies.

NP_2 in either side to generate the $NP_1+P_{(-tai)}+NP_2$ construction. That means the distributions, lexical meanings, lexical entry of the nouns occurred in the distribution of the NP_1 and NP_2 along with their correlations strongly influence changing the grammatical relations of the -TAI element in this construction. Consequently, the grammatical relations of the -TAI element in the construction can be defined without any limitation.

As a result, this study primarily aims to validate the aforementioned concept from a linguistic point of view, rendering this study methodologically significant for future researchers and scholars examining any language elements like the -TAI in the $NP_1+P_{(-tai)}+NP_2$ construction based on its I-structure not E-structure in order to translate into English and other languages.

2. Literature review

The literature review concerning the -TAI element, as a case marker, should commence with the researches on the case studies in the Mongolian language. In history of Mongolian linguistics, the case studies were initially introduced through the first grammar of Mongolian briefly entitled "Ankhadugar Jürkhen Tolt" written in 1243 by Sakya Pandita Kunga Gyeltsen (1182-1251) which has unfortunately not survived to the present day; however, it has been recorded in the subsequent grammar "Mongol üsegiin yosiig saitar nomloson khelnii chimeg" by Agvaandandar Lharampa. Since that time, it has been a fundamental subject of the Mongolian language studies according to D.Tumurtogoo (1981:403–445), which have touched upon their classifications by Sh.Luvsanvandan (1951, 1955, 1964a, 1964b, 1968a, 1968b, 1968c; 1978), D.Tumurtogoo (1981); M.Bazarragchaa (1997, 2005, 2008); their semantics by J.Street (1963), G.Abamasu (1977), D.Badamdorj (2001:94–104); M.Bazarragchaa (2005:141–149), Ts.Otgonsuren (2022); their alternatives and historical development by D.Tumurtogoo (1968:250–252), P.Byambasan (1983:302–305), Ch.Altanzagas (1997), M.Saruul-Erdene (2002:38–42), Ts.Otgonsuren (2012); their functions by Sh.Luvsanvandan (2010), D.Zayabaatar et al., (2016), Ts.Otgonsuren (2017); and in accordance with universal grammar by V.Dashdavaa (2012), M.Uuganbayar (2009:109–111; 2011:62–66) and Ts.Otgonsuren (2022).

Even though, some independent studies on the -TAI element are notably limited as the followings: Sh.Ozawa (2002:61–64) first proposed that the suffixes -TAI and its alternatives -TU and -TAN were gender-specific and numerical distinctions: the -TAI indicated feminine and the -TU masculine, but the -TAN plural form in the Middle Mongolian language. Khasbagana (1996:321–322) further examined the aforementioned concept and determined that the -TAI was a feminine alternative of the -TU which employed to derive adjectives from nouns, with resulting words serving as adjectives that denoted the relations. Also, Norjin (1981:53) clarified that the -TAI element was a suffix to derive adjectives from nouns, with an abstract meaning from the literal meaning of the corresponding noun, and elucidated how to distinguish this suffix from the comitative case marker. Ch.Altanzagas (1997) defined the distinction between the meanings of the -TAI and -TU elements in the modern Mongolian language and then examined the case system as well as the alternatives, origin, multiple meanings, forms, distributions and syntactic features of the -TAI element as comitative case marker. Ts.Otgonsuren (2012) defined some specific syntactic functions of the -TAI element and its alternatives -TU and -TAN in "the Secret History of the Mongols" based on their distributions preceding nouns, verbs, postpositions and conjunctions, and concluded that 1. The original meaning of the -TAI element which denoted the relations has evolved into a comitative case marker in Modern Mongolian; 2. The -TU has retained a solely modifying function for nouns; 3. The -TAN has served as a suffix for deriving nouns from adjectives.

3. Method

As the NP_1+P+NP_2 construction generally represents a higher-level of word and a lower-level of clause in grammatical hierarchy, its examination at the higher level - clause is methodologically crucial for a comprehensive definition of this construction.

In order to define the syntactic and grammatical relations of the -TAI element in the $NP_1+P_{(-tai)}+NP_2$ construction in Mongolian, the diachronic and synchronic approaches were followed:

a. Diachronic Analysis: We collected and analysed all occurrences using -TAI element and its alternatives in "the Secret History of the Mongols" which is considered to be a written monument of Mongolian language, literature, history, culture and tradition, etc. dated back to the 13th century for their structures and distributions.

b. Synchronic Analysis: We created a corpus of literature in Mongolian from which a large number of occurrences were collected and observed for some hypothesis, explanations, analysis, descriptions and then confirmations for some phenomena of the target element. As the core theory of this study, the following theories, principles, rules, etc. of the Universal Grammar, developed by N.Chomsky (1957, 1965, 1981, 1985) and followed by most linguists including P.Sells (1987), V.Cook (2000), A.Carnie (2000), are practically used like:

- The Phrase Structure Rule for the basic structure of the $NP_1+P_{(-tai)}+NP_2$ construction;
- Government, the Head Parameter and the X-bar theory for defining the syntactic and

grammatical relations of the (relational) elements -TAI in the $NP_1+P_{(-tai)}+NP_2$ construction;

- The Transformation rule for the movements of the elements;
- The θ-theory for the definition of the grammatical relations of the elements and construction;
- Projection Principle for the requirement of the relevant and other elements in the $NP_1+P_{(-tai)}+NP_2$ construction, etc.

c. Mini-Survey Analysis: A descriptive quantitative mini-survey was conducted among 65 undergraduate English majors at the National University of Mongolia to explore how learners navigate the relation between the English preposition WITH and the Mongolian suffix -TAI.

4. Results

To conduct this study comprehensively, a three-fold analytical approach was employed. The first phase involves a diachronic analysis, comparing the -TAI element and its alternatives within 13th-century texts to establish a historical baseline. This is followed by a synchronic analysis to examine its modern manifestations, and finally, a learner survey to investigate the practical application of these relations in translation.

4.1. Diachronic Analysis

A diachronic analysis was, as being peripheral to this study, conducted using the Secret History of the Mongols, a well-known historical and literary text from the Middle Mongolian period. A total of 59 occurrences of the -TAI element were identified (See also Figure 1): 41 occurred before noun phrase in $NP_1+P_{(-tai)}+NP_2$ construction like in (4-5), 16 before verb phrase in $NP+P_{(-tai)}+VP$ construction (6-7) and 2 before postposition (8). Notably, these distributions have remained stable over time. Out of the 41 occurrences, 33 functioned as relational elements like in (4), while 8 as suffixes like in (5) according to Ts.Otgonsuren (2012).

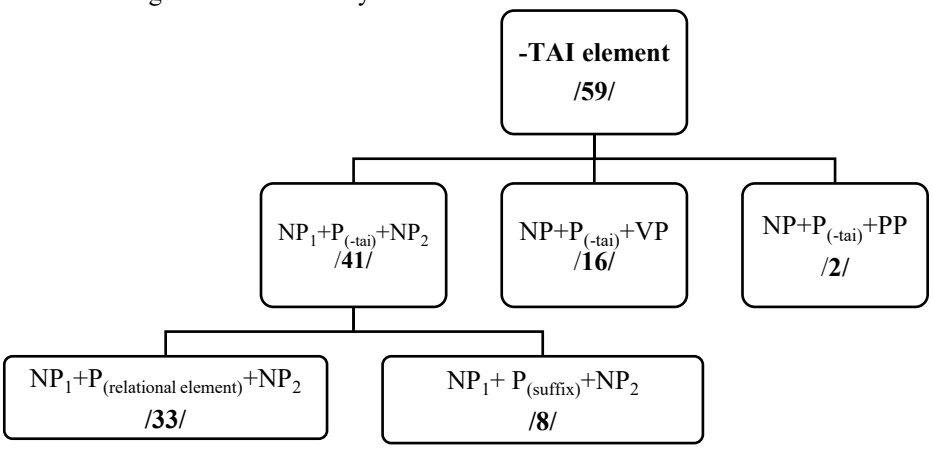


Figure 1. Distributions of the -TAI element in "the Secret History of the Mongols"

(4) a.…*barqujin-qo'a-ca tőre[k]sen alan-qo'a* ***nere<u>tei</u>*** ***<u>ők</u>in*** *tere* (Rachewiltz, I, 1972:14, Section 8)

b. *That [was] the maiden which was born of Barγujin Go'a of … and named Alan Go'a* (Cleaves,F.W, 1982:2)

c. *… Barqujin-qo, …, had given birth to the girl Alan Qo-a* (Urgunge Onon, 2001:40)

(5) a. *… qunar mawu cilger bi* ***<u>qutuq</u>tai su<u>tai</u>*** *ű<u>jin</u>-i quriyaju iregű bolun qotola merkit-e huntawu* (Rachewiltz, I, 1972:46, Section 111)

b. *I, qunar and bad Čilger,*

In gathering the happy and fortunate Üjin,

Am become a plague unto all the Merkid (Cleaves,F.W, 1982:46)

c. *… Barqujin I, Chilger, who am doubly bad, became the keeper of the fortunate*

and mighty Lady, … (Urgunge Onon, 2001:92)

(6) a. *… tende hő'elűn-ű<u>jin</u>* ***<u>ke'eli<u>tei</u></u>*** ***<u>bűrűn</u>***…(Rachewiltz, I, 1972:24, Section 59)

b. *… then, when Hö'elün Üjjin was with child, … Činggis Qahan was born*

(Cleaves,F.W, 1982:14)

c. On his return, Lady Hö'elün was pregnant (Urgunge Onon, 2001:56)

(7) a. *…caqa'an teme'en kőljű qara'utai* ***<u>terge<u>tei</u></u>*** *sőni-de dűlin <u>yorciju</u>…* (Rachewiltz, I, 1972:140, Section 244)

b.*…it having been [yet] night, straightway harnessing a white camel, departed in a black cart, travelling all the night* (Cleaves,F.W, 1982:177)

c. *… Mother harnessed her white camel to the black wooden-framed covered cart [that] very night and travelled after them through the night …* (Urgunge Onon, 2001:226)

(8) a. *… üdür mőr-dűr-iyen yabuju* ***<u>nara<u>tai</u>-<u>a</u></u>*** *kebte'űl-e jayilaju qadana qonotuqai* (Rachewiltz, I, 1972:167, Section 278)

b. *… after that the sun shall be set, let the nightguards seize and [thus] pass the night…* (Cleaves,F.W, 1982:220)

c. *… are to follow their own paths [during] the day and, at sun [set], yield to the night-guards and spend the night outside* (Urgunge Onon, 2001:271)

In Middle Mongolian, the marker *-a* in the *nartai-a* in (8) functioned systematically as *aqui* serving as a functional equivalent to the English copular verb "to be". Over time, this form underwent a process of reduction into the postposition *-a*. This transformation in its E-structure can be attributed to the principle of the language economy where phonetic and structural erosion occurs to optimise processing efficiency.

The considerably frequent occurrence of the -TAI element in the classical original (Mongoliin Nuuts Tovchoo, 2009) suggests that the -TAI element has gained prevalence in modern Mongolian, reflecting its development. In traditional linguistics, the initial noun preceding the -TAI element is considered to be a modifier of the noun that follows the -TAI element. But, the universal grammar implies that it functions as a suffix for deriving adjectives from nouns ($NP_1+P_{(suffix)}+NP_2$ construction), as well as a connector between the two nouns (NP_1 and NP_2) and relational element connecting them ($NP_1+P_{(relational\ element)}+NP_2$) construction, in the Middle and Modern Mongolian languages.

4.2. Synchronic Analysis

To further corroborate the findings from the diachronic analysis and examine specific features in the contemporary context, a synchronic analysis focused on the -TAI element in the $NP_1+P_{(-tai)}+NP_2$ construction

which is the most ambiguous in the Modern Mongolian. We assembled a corpus of 84,000 words, in which 227 occurrences of the -TAI element in the $NP_1+P_{(-tai)}+NP_2$ construction were identified and analysed to develop hypotheses and confirmations. The quantity of these occurrences is notably substantial. The -TAI element predominantly serves to connect nouns to verbs (N+V) as an adjunct, conveying the meanings with, together with or along with as a comitative case marker. It denotes such grammatical relations rather than connecting nouns to nouns (NP_1+NP_2) directly in a sister-relation; instead, it connects indirectly in a daughter-relation through the verb, which presents challenges for syntactic transformations in the E-structure.

Within the scope of our analysis of the 227 occurrences, the -TAI element in the $NP_1+P_{(-tai)}+NP_2$ construction in Modern Mongolian was classified into two fundamental types based on their syntactic properties as outlined below (See also the Figure 2).

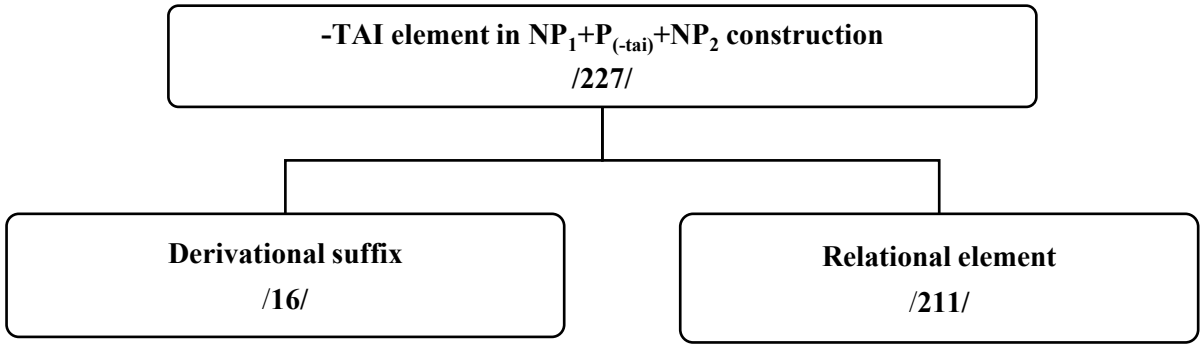


Figure 2. Syntactic properties of the -TAI element in the $NP_1+P_{(-tai)}+NP_2$ construction in Modern Mongolian

a. Derivational suffix: 16 occurrences derived adjectives from nouns often expressing the meaning of possession. For example, *gaikhal**tai** khot* (a wonderful city) incorporates a noun *gaikhal* (a wonder) and the suffix -TAI, creating an adjective *gaikhaltai* (wonderful). This mirrors the English practice of adding the suffix -full to the noun wonder to derive the adjective wonderful.

b. Relational element: 211 occurrences showed that the -TAI element contributed the grammatical relation of with or together and possession. For example, the term *ünertei* (with scent) in the $NP_1+P_{(-tai)}+NP_2$ construction *üner**tei** us* (perfume) does not simply mean water with scent, but rather refers to a specific product, known as perfume.

The diachronic and synchronic analyses of the -TAI element in the Middle and Modern Mongolian languages generally reveals a stable ratio of the relational element to the derivational suffix both conveying the same meanings of possession and having. However, it is essential to underline that the fundamental aspect of these analyses pertains to the relational element -TAI in the $NP_1+P_{(-tai)}+NP_2$ construction in Modern Mongolian, distinguishing it from the derivational suffix -TAI.

4.3. Learner Mini-Survey Analysis

The third phase of the study specifically investigates how learners perceive and process the grammatical relations of the -TAI element within the Mongolian language. While the survey included a parallel English section for baseline comparison, this analysis focuses exclusively on the Mongolian data to determine whether Mongolian native speakers can correctly identify the syntactic head (the modified word) of the -TAI element in their L1. The participants analyzed the Mongolian sentences categorized into two basic syntactic constructions: a. $NP+P_{(-tai)}+VP$ and b. $NP_1+P_{(-tai)}+NP_2$.

The analysis of 65 responses revealed a distinct pattern in how native speakers process the -TAI element:

a. $NP+P_{(-tai)}+VP$: Learners demonstrated high proficiency in recognizing -TAI as a verb modifier (Adjunct). In verb phrases extracted from the corpus, the majority correctly identified the relation to the predicate like in (9).

(9) a. *baiguullaga**tai** ajillaj irjee*
b. *organization*-SING, DET, COM *work*-PRSPRF
c. *has worked with the organization*

This suggests that because Mongolian is a verb-prominent (SOV) language, speakers naturally gravitate toward connecting relational elements to the main verb.

b. $NP_1+P_{(-tai)}+NP_2$: It has two distinct constructions in Mongolian, which align with the functional distinctions established in Section 4.2. The first involves the derivational suffix, where learners processed a phrase such as (10):

(10) a. *gunig**tai** setgel*
b. *sadness*-COM *heart/feeling*
c. *sad feeling* / *sad heart*

In such NP constructions, the noun *gunig* (sadness) combines with the suffix -TAI to derive the adjective *gunigtai* (sad), directly modifying the head noun *setgel* (heart/feeling). Because this derivational process mirrors English adjective formation, accuracy was moderate. Learners often avoided mechanical or literal translations (e.g., *a heart with sadness*) and instead relied on semantic cues of "possession" rather than purely syntactic analysis to correctly produce the adjective phrase.

Conversely, when processing the relational element (as distinguished in Section 4.2), the most significant finding was the remarkably low accuracy rate of

15.4% in translating these constructions. In complex phrases extracted from the corpus, learners frequently defaulted to a mechanical "Form-to-Form" translation. For instance, in the following phrase, they inserted the preposition WITH because of the -TAI suffix acting as an adjective derived from a noun like in (11):

(11) a. *khorin dörvön salaa ever**tei** ukhaa dönön buga*

b. *twenty four branch antler*-COM *light bay four year old deer*-SING, NOM

c. a *light bay four-year-old deer with twenty-four-tined antlers* (in literal translation based on its E-structure)

d. *a light bay four-year-old deer which has twenty-four-tined antlers* (in accurate translation based on its I-structure)

Common errors included treating it as a simple possession or instrumental adjunct, failing to recognize the deeper grammatical relation. A natural English translation would require a structural shift based on its I-structure. The learners' failure to recognize the exact relation between NP_1 and NP_2 led to these literal translation breakdowns.

The data confirms a critical blind spot in the processing of the I-structure in Mongolian. Native speakers tend to over-generalize the -TAI element as a verbal adjunct due to the SOV structure of the language. This failure to recognize -TAI as a noun-modifier in NP constructions causes "Form-to-Form" translation errors, where learners mechanically translate -TAI as with, missing the opportunity to use relative clauses or specific adjectives required in English.

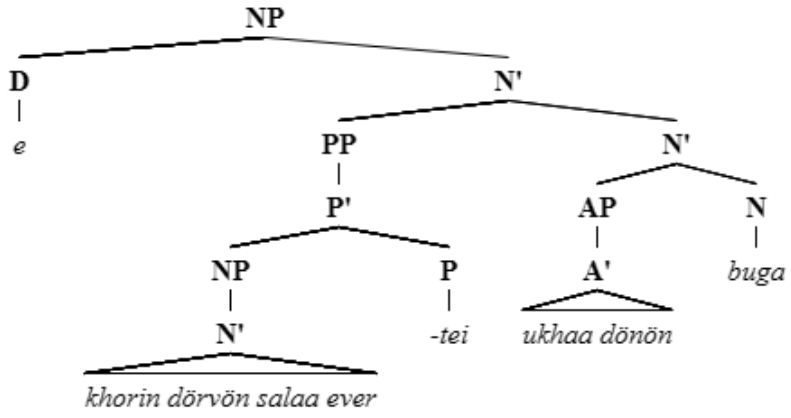


Figure 3. Representation of the NP_1+$P_{(-tai)}$+NP_2 construction in the E-structure

As illustrated in the X-bar tree diagram above, the Mongolian relational element -TAI functions as the syntactic head (P), taking the preceding noun phrase *khorin dörvön salaa ever* (NP_1) as its complement to form a Postpositional Phrase (PP). Consequently, this entire PP acts as a modifier for the subsequent noun phrase *ukhaa dönön buga* (NP_2), merging under a single maximal projection, the highest NP node.

However, translating this E-structure literally into English using the preposition with (e.g., *a light bay four-year-old deer with twenty-four-tined antlers*) distorts the relation of possession, potentially implying an instrumental or comitative case (*as if the deer is merely standing next to or carrying the antlers*). Therefore, relying on its I-structure - which reveals the deeper grammatical relation of inalienable possession (i.e., *the deer inherently possesses the antlers growing on its head*) - proves that a structural shift using a relative clause (*a light bay four-year-old deer which has twenty-four-tined antlers*) is the most accurate and linguistically sound approach for translation.

5. Discussion

A word is not an element which occurs in any firmly fixed distribution in a sentence and solely conveys a certain meaning wherever it occurs. So it is general and abstract as a single element but it gets more obvious and disambiguous in its relation to other elements within its higher level of the grammatical hierarchy - a phrase, clause and sentence then. Likewise, the -TAI element cannot be entirely defined in a lexicon or dictionary when it is a single element. The definitions of the grammatical relations of the -TAI element vary depending on which elements are connected by in the NP_1+$P_{(-tai)}$+NP_2 construction in particular. Although the fundamental relation of this element is possession, the relations are mutable based on the distribution, lexical meaning, lexical entry, and correlation of the nouns or noun phrases which occur in the distribution of the NP_1 and NP_2. As a result, the grammatical relations of the -TAI element in the NP_1+$P_{(-tai)}$+NP_2 construction is limitless like in (12-16), however their classification or systemisation is constrained, on contrary.

(12) a. *avdraaraa düüren nom sudar**tai** övgön* (Rinchen B, 1945)

b. *book and sutra*-PLU, COM (ACC) *old man*-SING, NOM

c. *an old man with many books and sutras*

d. *an old man who has many books and sutra*e. *an old man (who has) kept/collected many books and sutras* (in this context)

(13) a. *altan khargana**tai** tolgoi* (Lkhagvasuren B., 1979)

b. *caragana*-COM (POSS) *hill*-SING, NOM

c. *a hill with a full of caragana*

d. *a hill (which is) covered in/dominated by caragana*

e. *a caragana-covered hill*

(14) a. *tsasan deer buugaad baisan nisdeg tereg**tei** erliin bagiinkhan* (Ayurzana G., 2002)

b. *helicopter*-SING, COM (TRANS) *search and rescue team*-SING, NOM

c. *a search and rescue team with a helicopter*

d. *a search and rescue team who has a helicopter*

e. *a search and rescue team (who is) using a helicopter* (in this context)

(15) a. *ailiin aduund baisan daagatai güü-g avchrakh*...(Lkhagva Zh., 1970)

b. *foal*-SING, COM (POSS) *mare*-SING, NOM

c. *a mare with a foal*

d. *a mare (who) has a foal* (in this context)

e. *a mare (who is) followed by her foal* (can be in other context in Mongolian)

(16) a. *moritoi khün tsastai tald süreg chonoos zugtaad* ...(Jiang Rong, 2010)

b. *horse*-SING, COM (ACT) *man*-SING, NOM

c. *a man with a horse*

d. *a man (who is) riding a horse* (in this context)

e. *a man (who) has a horse* (can be in other context in Mongolian)

f. *a man (who) is lucky* (can be in other context in Mongolian)

But, all the relations of the -TAI element in the $NP_1+P_{(-tai)}+NP_2$ construction can be defined and elucidated entirely, abstracting this construction in its I-structure or initial-structure. The -TAI element is identified as a comitative case marker, serving as an adjunct that conveys meanings of 'with' and 'together' in verb phrase, and as the second active element after the -IIN/-NII element [46] in the NP_1+P+NP_2 construction in Mongolian. This property is expected to enhance the uniqueness of the -TAI element, which can be apparently evidenced in the following examples. Namely, the initial (17) reveals the grammatical relation in an abstract way that when the -TAI element connects *khas tamga* (a swastika sign) and *dörööö* (stirrup) just in this specific linear order, it generally provides a distinct meaning *the stirrups with swastika sign* in its E-structure, but *the stirrups with a swastika sign engraved on* or *the stirrups on which a swastika sign has been engraved* in its I-structure or initial-structure regarding the lexical meanings, lexical entries and correlations of the both nouns in the NP_1 and NP_2.

(17) a. *Övög deedes chine khas tamgatai döröögöö multalj*…(Galsansukh S., 1996)

b. *swastika sign*-SING, COM (POSS) *stirrup-e* (PLU), NOM

c. *stirrups with a swastika sign*

d. *stirrups which has a swastika sign*

e. *a pair of stirrup on each of which a swastika sign has been engraved*.

In the next example (18), the -TAI element connects the nouns *gerel* (light) and *tsonkh* (window) in the $NP_1+P_{(-tai)}+NP_2$ construction. If translated literally into English in its E-structure, it refers to the windows with lights indicating the windows that have lights or windows through which lights entered the rooms of the apartment (from outside into inside). As this context tells the windows of the rooms in which the lights have been turned on in its I-structure, it is plausibly confirmed that the grammatical relations of the -TAI element is quite variable in each context.

(18) a. *Zergeldee suutsnii barilguudad geltei tsonkh olon, khöshigtei khöshiggui, delgeestei delgeesgüi yanz bür* ... (Bayarsaikhan P, 2017)

b. *light*-e (PLU), COM (ACC) *window*-e (PLU), NOM

c. *windows with lights*

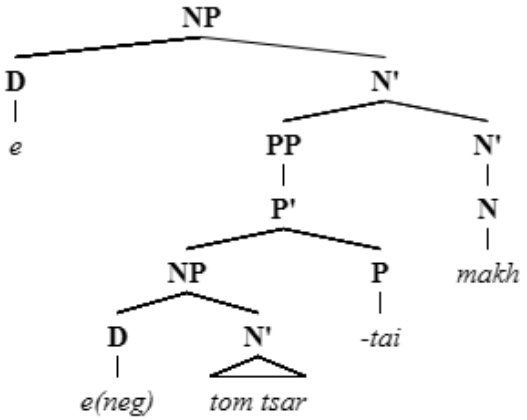
d. *windows with the lights in the rooms*

e. *windows of the rooms in which the lights have been turned on*

In summary, the grammatical relations of the -TAI element depend upon the nouns which occur in the distributions of the NP_1 and NP_2; however, as the NP_2 serves as the head word in the $NP_1+P_{(-tai)}+NP_2$ construction in Mongolian which adhere to an SOV structure and the Head and Parameter Principle, the lexical meanings at first, and lexical entry and their correlation, as well as the syntactic relations: sister-relation and daughter-relation are also crucial in defining the grammatical relations of the -TAI element. For example, in the *tom tsartai makh* in the next example (19), the NP_2 governs the NP_1 with a meaning that the *makh* (flesh as NP_2) does not contain *tsar* (*a big metal dish*, as NP_1), but tells the result of an action which *some flesh was put/served on the big metal dish*. This kind of relation is capable to be represented through merely a daughter-relation, not a sister-relation according to the Universal Grammar.

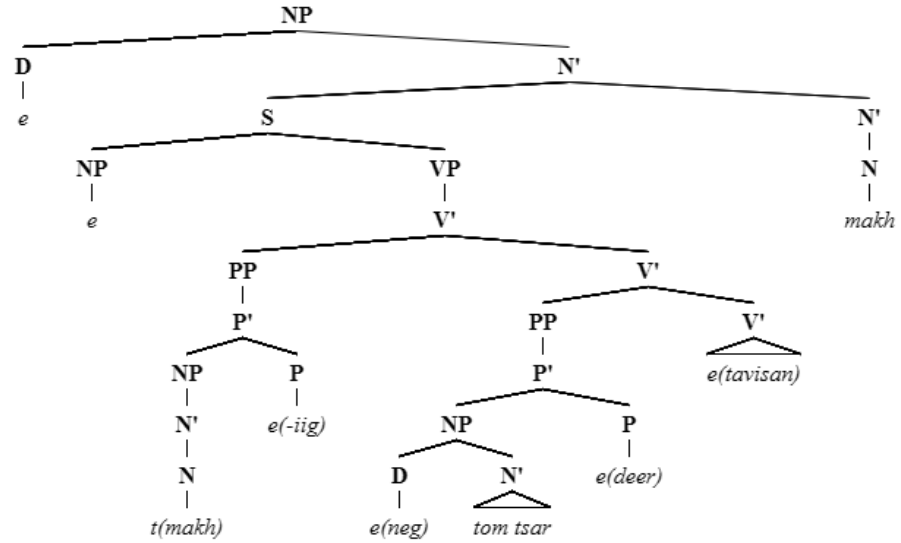
(19) a. *Galsmaa gerees tom tsartai makh barin garch ireed bars bolon busad nokhdiig shagnalaa* (Jiang Rong, 2010)

[46] The author has defined through the I-structure that the -IIN/-NII elements in Mongolian indicate 22 grammatical relations, and OF in English around 22 at least (Otgonsuren Ts, 2022).

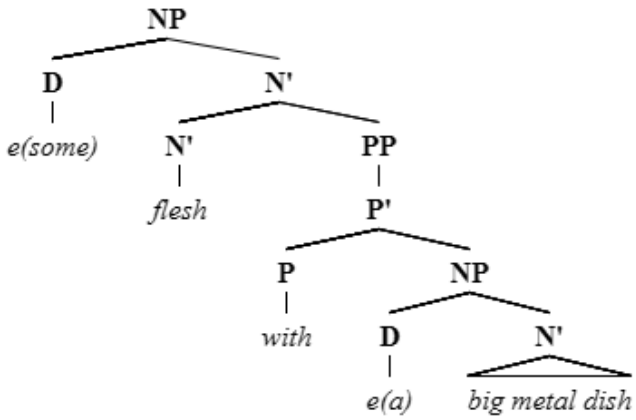


b. § *b. §§*

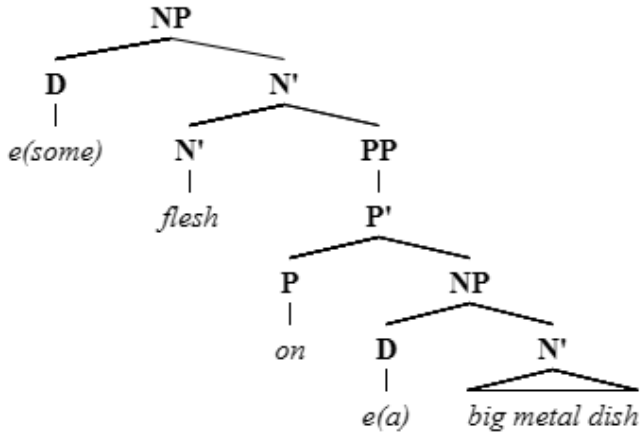
c. *big metal dish*-SING, COM *flesh*-U, NOM



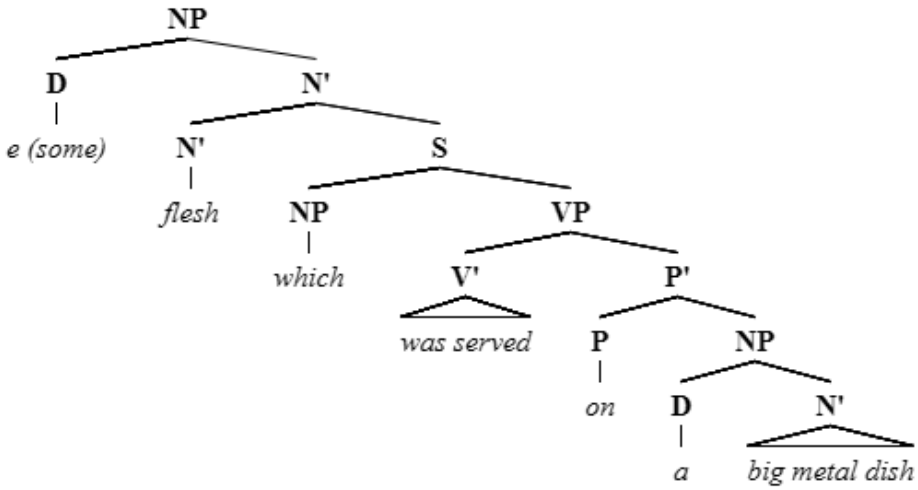
d. *some flesh with a big metal dish* (in literal translation based on its E-structure)



e. *some flesh on a big metal dish* (in semantic translation)



f. *some flesh which was put/served on a big metal dish* (in accurate translation based on its

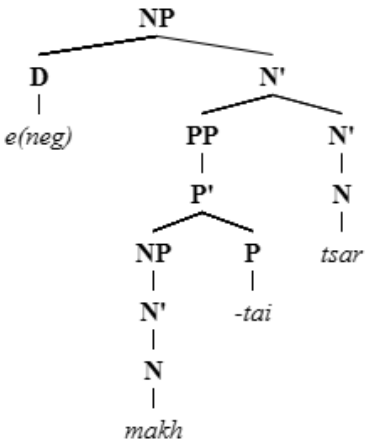


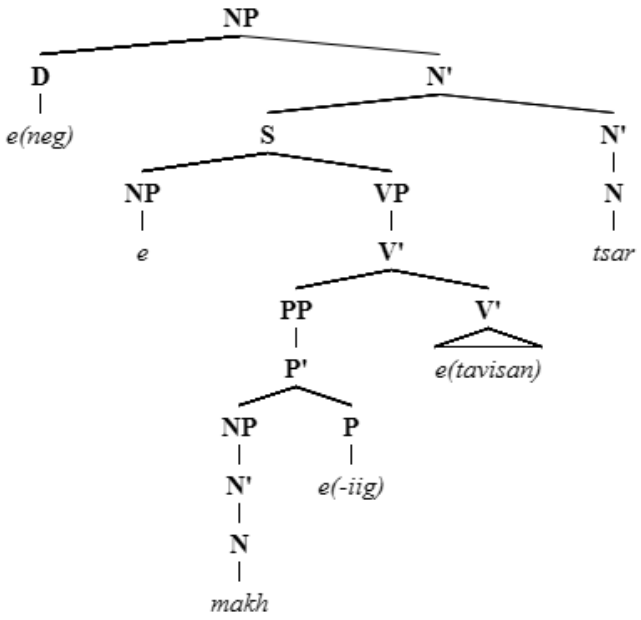
I-structure)

The three examples (17-19) aim to highlight the capacity of the -TAI element that it denotes distinct grammatical relations connecting different nouns in the NP_1 and NP_2, despite generating the $NP_1+P_{(-tai)}+NP_2$ construction with the same distribution and function.

But it is intriguing that the grammatical relations of the -TAI element can be altered due to the distributions of the nouns changed in the NP_1 and NP_2, even though the $NP_1+P_{(-tai)}+NP_2$ construction is generated by the same nouns as illustrated in the following example (20). Unfortunately, it is frequently ignored by English language learners specifically. All elements in the distribution of the NP_1 and NP_2 in the above mentioned example (19) keep their identical syntactic relations but exhibit a significant variation in grammatical relations radically when their distributions are reversed.

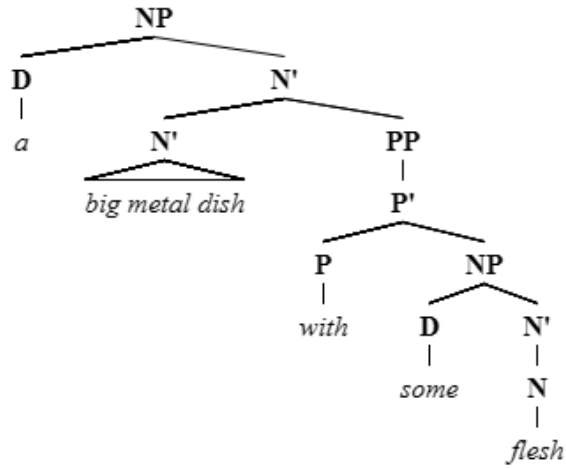
*a. <u>makh**tai** tsar</u>*



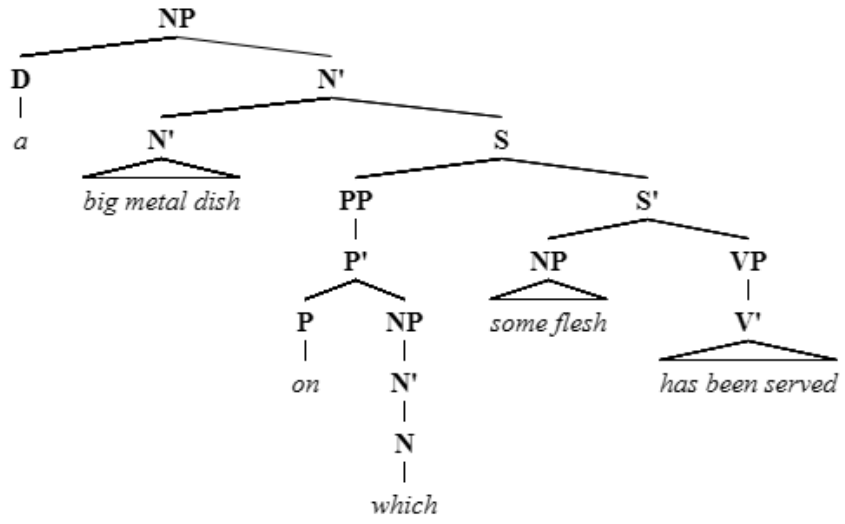


b. § *§§*

c. flesh-U, COM big metal dish-SING, NOM



d. a big metal dish with some flesh (in literal translation based on its E-structure)



e. a big metal dish on which some flesh has been served (in accurate translation based on its I-structure)

6. Conclusion

Previously, the -TAI element in the $NP_1+P_{(-tai)}+NP_2$ construction was considered to consistently denote the grammatical relation of 'possession'. This study, however, has shown that the -TAI element functions syntactically by generating the $NP_1+P_{(-tai)}+NP_2$ construction through daughter relation between NP_1 and NP_2 and denotes a general grammatical relation of 'a trace or result of an action that has already been performed'. Despite this, the relevant element can, in an abstract way, denote nearly infinite grammatical relations in the I-structure, relying on the distributions, lexical meanings, lexical entries and correlations of all elements in the $NP_1+P_{(-tai)}+NP_2$ construction. This is because any individuals do not employ a single element when using a language, and the single elements lack the capacity to entirely express their ideas.

In summary, the phenomena observed on the relational element -TAI in the $NP_1+P_{(-tai)}+NP_2$ construction in this study reflects limitlessly to Mongolian, or English, as a fundamental property of human language. The human language acts as an external representation of human thought, that is to say, the human thought is encoded in the I-language, which is universal and embodied in the human mind, but articulated through the E-language. Hence, we should priorly define the I-structure that provides a more perfect alternative of translation in meaning and style.

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Abbreviations

ACC	Accusative
ACT	Action
COM	Comitative case
INSTR	Instrument
NOM	Nominative case
PLU	Plural
POSS	Possession
PRSPRF	Present Perfect Tense
SING	Singular`
TRANS	Transportation
U	Uncountable

THE "LITTLE MAN" AND HIS SOCIAL LIFE IN THE WORKS OF JAMES BALDWIN

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Abstract

The concept of the "little man" is widely used in literature to describe ordinary individuals whose lives are shaped by social pressures and personal struggles. In the works of James Baldwin, this concept is closely connected with issues of identity, race, and belonging. J.Baldwin presents characters whose experiences reveal deeper social realities and internal conflicts.

This article examines the depiction of the "little man" and his social life in J.Baldwin's prose. Attention is paid to how external circumstances and personal experiences affect the individual's position in society. The analysis is based on selected works, including "Go Tell It on the Mountain", "Notes of a Native Son", and "Giovanni's Room". The study shows that J.Baldwin portrays the "little man" as a thoughtful and complex individual who seeks self-understanding and a meaningful place in society.

Keywords: little man, social life, identity, society, James Baldwin

Introduction. The image of the "little man" has an important place in world literature. It usually refers to an ordinary person whose life is limited by poverty, social inequality, prejudice, and the pressure of society. In American literature, this image became especially significant in the twentieth century, when writers increasingly focused on the problems of everyday people and their struggle to find their place in society.

Among the writers who developed this theme, James Baldwin occupies a special position. J.Baldwin's works examine the lives of people who experience social isolation, discrimination, and inner conflict. His characters are not heroic figures in the traditional sense; they are ordinary individuals whose daily lives are shaped by racial inequality, family pressure, loneliness, and the search for identity. Through these characters, J.Baldwin presents the "little man" as a person who tries to preserve dignity and self-respect in difficult circumstances.

The theme appears clearly in J.Baldwin's major works such as "Go Tell It on the Mountain", "Notes of a Native Son", and "Giovanni's Room".

In "Go Tell It on the Mountain" the young protagonist struggles with religious expectations, family conflicts, and the desire to understand himself (Baldwin, 1953).

In "Notes of a Native Son" J.Baldwin shows how racial discrimination influences the individual's inner world and social life (Baldwin, 1955).

In "Giovanni's Room" the problem of social exclusion relates to personal identity and the fear of being different (Baldwin, 1956).

Together, these works show that J.Baldwin's "little man" is deeply influenced by society but continues to search for meaning and belonging.

Researchers have different views on the representation of the individual in literature. Some scholars emphasize the social conditions that shape the character, while others focus on the psychological and emotional aspects of the individual's experience. In this context J.Baldwin's works combine both approaches, presenting the "little man" as a figure formed by both external social forces and internal personal struggles (Elam, 2015, p.18).

Discussion. In the work of James Baldwin, the concept of "little man" is an artistic model of an individual who is formed within a social structure but is constantly limited by that structure. The main feature of this image is the disclosure of broader social and ideological systems through his everyday life experience. J.Baldwin constructs the text as a field of continuous interaction between the inner world of the individual and social reality, and in this plane the position of the "ordinary person" is presented as the result of complex social mechanisms.

In the novel "Go Tell It on the Mountain", the image of John Grimes acts as one of the initial forms of the "little man" model. Here, the social life of the individual is closely connected with family relationships, religious discourse and the moral expectations of society. John's everyday experience shows that although religious institutions guide the spiritual development of the individual, they also create a normative system that limits his possibilities for inner freedom (Baldwin, 1953).

In the structure of the novel, the church environment works as a mechanism of social control and frames the individual's possibilities for self-expression. John's self-understanding process is formed within this framework, and his search for identity creates a tension between social expectations and individual desires. From this perspective, the image of the "little man" is presented not as a passive result of the socialization process, but as a conscious subject bearing the internal contradictions of that process.

In the environment in which John Grimes lives, family relations are determined by mechanisms of power and obedience. Gabriel Grimes' authoritarian behavior shapes the family as a system of emotional unity

and normative control. The institution of the family, instead of expanding the possibilities of self-expression of the individual, directs him to certain behavioral frameworks.

Religious discourse occupies a central place in the structure of social life in the novel. The church environment acts as an institutional system that creates collective identity and regulates individual behavior. J. Baldwin presents religious experience as a means of spiritual growth and a mechanism of social control. According to research, religion in the novel shapes the psychological state of the individual through the dualism of "salvation and sin", which creates tension, especially in the process of self-perception of the teenager John. (https://www.litcharts.com/lit/go-tell-it-on-the-mountain/themes/faith-and-religion)

In this context John Grimes's social life is structured around three main lines of pressure: family expectations, religious ideology, and racial-social reality. These three constantly interact in the subjective world of the individual, resulting in an ambiguous state of identity. As Encyclopedia.com notes, the novel's main thematic line is precisely the "quest for self-discovery" and the constant redirection of this quest by the social structure.
(https://www.encyclopedia.com/arts/educational-magazines/go-tell-it-mountain).

John's self-awareness process is presented as a fragmented model of consciousness. On the one hand, he is accepted by the church as a "chosen soul", and on the other hand, he struggles with his personal desires and inner fears. This situation makes his social position not stable, but changeable and contradictory. In this regard, the image of the "little man" acts not as a passive social result, but as a conscious subject constantly reformed within the structure.

A special point of attention in J. Baldwin's style is that the inner monologue of the individual is a direct product of the social system. That is, John's thought model is inseparable from the ideological structures of the social environment in which he lives. This approach is explained by the concept of "internalized ideology" in social theory and shows that the process of individual self-awareness is formed under social determination.

The Harlem environment of the novel also plays an important role in the formation of social control and identity. Harlem is presented as both a place of safety and an urban space where restrictive social structures are manifested. This dual nature limits the individual's social mobility and makes their future opportunities uncertain. (https://www.ebsco.com/research-starters/literature-and-writing/go-tell-it-mountain-analysis-major-characters).

The image of John Grimes, as the initial form of the "little man" model, acts as a starting point for the transformation of internal consciousness. In J. Baldwin's approach, the individual is not a passive product of the social system, but a reflective subject who bears the contradictions created by that system. This elevates the concept of "little man" from the simple social typology existing in classical literature to the level of a more complex, multilayered identity model.

In "Notes of a Native Son" James Baldwin organically connects personal experience with historical and social context, presenting the image of the "little man" in a broader ideological framework. In this work, the individual no longer acts as a product of the family and local environment, but as a complex subject formed under the influence of systemic racism, social inequality and historical traumas existing in US society. Baldwin's approach shows that the social structure is not only determined by the life opportunities of the individual, but also directly affects his psychological state and the process of self-perception (Baldwin, 1955).

One of the most important features of the work is its writing in essay form. This form allows J. Baldwin to present personal memory and social events in parallel. In the particularly famous essay "Notes of a Native Son" the author describes the death of his father and the racial riots in Harlem within the same time frame. This structure creates a strong parallel between individual trauma and collective social tension. Researchers note that with this approach, J. Baldwin uses personal experience as an "analytical window into social history." (Leeming, 1994, p.47).

In this context, the image of the "little man" is not presented as a passive result of the social system. On the contrary, he becomes a reflective subject who perceives and interprets the reality he experiences. Houston A. Baker Jr., analyzing the structure of Baldwin's essay, emphasizes that the author creates a "social form of psychological realism" by linking the internal processes of the individual's consciousness with social ideology. (Baker, 1984). This shows that the internal transformation of an individual is not only the result of personal experience but also shaped by the influence of social structures. On the other hand, Robert A. Bone, while analyzing Baldwin's work, notes that the author presents the experience of the African American individual as a "moral and historical dilemma" of US society. (Bone, 1965). This approach further expands the concept of "little man" and allows him to be interpreted as a bearer of historical memory.

The description of the Harlem environment in the work also plays an important role in the formation of social consciousness. The urban space is presented as a place where social tensions and racial conflicts accumulate. In this environment, the daily life experience of the individual is closely connected with social conflicts and determines his emotional reactions. Academic sources note that Baldwin presents Harlem as "a place where personal and collective trauma intersect." (Ostberg, 2026).

J. Baldwin's attitude to his father in the essay is of analytical importance. Although the father's harsh and closed character expresses family conflict at the individual level, in a broader sense this image acts as a symbol of psychological defense mechanisms formed under racial oppression. When analyzing the life of his father, Baldwin shows that social injustice produces long-term psychological consequences, and these consequences are transmitted from generation to generation (Leeming, 1994).

In this context, individual memory becomes an integral part of social memory. Baldwin's narrative strategy presents the individual life story as part of collective history. This raises the image of the "little man" to a more complex level, since the individual no longer only lives his own life, but also acts as a carrier of historical processes.

In “Giovanni’s Room” James Baldwin takes the “little man” model to a deeper existential and psychological level. In the work, the social life of the individual is no longer determined solely by the influence of social institutions, but by personal identity, especially emotional self-perception. In this regard, the image of David stands at the center of the tension that arises between social norms and individual desires, and this tension shapes his entire life trajectory (Baldwin, 1956).

The main conflict line of the novel arises between the individual’s acceptance of his inner truth and the behavioral models that society expects of him. Researchers note that David’s internal split arises from his desire to conform to the requirements of a heteronormative society and his personal desires. This situation shows that Baldwin presents the issue of identity not only as a social category, but also as a deep psychological process. (Field, 2015).

The place of Paris has a special symbolic meaning in the work. At first glance, this city is associated with social freedom and individual choices. However, the development of the novel shows that the change of place does not eliminate the internal conflicts of the individual. On the contrary, David's experience in Paris exacerbates his internal crisis. This is explained in literary criticism as a “geographical escape illusion”; that is, the individual cannot escape social and psychological problems by changing places.

The relationship between David and Giovanni clearly demonstrates how the fear of social acceptance affects individual relationships. Although David's feelings for Giovanni are real and deep, he rejects this relationship for fear of not being accepted by society. This does not indicate the internal weakness of the image of the “little man”, but, on the contrary, the power of the pressure created by the social structure. David Leeming notes that Baldwin raises the problem of identity to an ethical and existential level in this novel by showing the social consequences of the individual's self-denial. (Leeming, 1994).

The image of Giovanni is an example of a more extreme marginalization within this system. He is presented as an individual who does not conform to social norms and does not hide his identity. However, his fate shows that identities that are not accepted by society often lead to tragic consequences. In this respect, Giovanni acts as a more radical form of the concept of “little man” — he represents an individual who remains on the fringes of the social system and is “punished” by that system. Literary critic Magdalena J. Zaborowska, while analyzing this novel by Baldwin, emphasizes that “Giovanni’s Room” not only shows that individual identity is a social construction, but also reveals how restrictive that construction is. (Zaborowska, 2002).

This expands the “little man” model, allowing it to be interpreted not only as a socio-economic category, but also because of cultural and psychological pressures.

The narrative structure of the novel also plays an important role in this analysis. The retrospective presentation of events provides David with a reflective approach to his own past. This reflection acts as an analytical process aimed at understanding the social life of the individual. Thus, Baldwin presents individual experience not only as events experienced, but also as a process that is subsequently understood and interpreted.

The "little man" here no longer acts as just an individual influenced by the social structure, but also as a complex subject trying to find his place within that structure but often experiencing internal fragmentation in the process. To understand the concept of “little man” in James Baldwin’s work in more depth, it is necessary to analyze it in comparison with other literary examples and theoretical approaches. The issue of social invisibility and marginal position of the individual has been widely explored in 20th century American literature. In this context, the work “Invisible Man” by Ralph Ellison is of particular importance.

In Ellison’s work, the “invisible man” represents an individual who is not accepted and recognized by society. In J.Baldwin, this invisibility is more associated with internal consciousness and social reflection. Researchers note that Baldwin explains the position of the individual in the social system not only through external influences, but also through how these influences are perceived in consciousness. (Ellison, 1952; Leeming, 1994).

J. Baldwin's "little man" model is associated with existential and humanistic traditions. Here, the individual is not only a product of the social structure, but also a subject who is faced with moral choices and understands the consequences of these choices. From this point of view, J. Baldwin's heroes are presented as individuals who face problems of freedom, responsibility and identity.

In modern social theory, the relationship between the individual and society is explained by the concepts of "structure" and "agency". Baldwin's works show a balance between these two concepts. Although the individual is formed under the influence of the social structure, he does not remain in a completely passive position.

J.Baldwin's heroes are distinguished by this very feature of agency: they perceive social pressures, but do not take a completely lost position in the face of these pressures. This is especially evident in the characters of John Grimes and David. Although both characters are formed within a social system, their internal reflection and self-awareness are the result of active thought.

J.Baldwin’s “little man” model is also consistent with intersectional approaches in contemporary literary criticism. According to this approach, an individual’s identity is formed at the intersection of several social factors — race, class, gender, etc.

The intersectionality theory put forward by Kimberlé Crenshaw shows that an individual’s social position cannot be explained by a single factor (Crenshaw, 1989). In this regard J. Baldwin's "little man" concept

can be considered a complex model that is consistent with modern theoretical approaches.

Conclusion. In the work of James Baldwin, the image of the "little man" is presented as a more complex and multifaceted model. Through this image, the author shows that a person's position in society is formed not only by external circumstances, but also by his inner thoughts and experiences.

The analysis shows that in J. Baldwin's works, although the individual is formed under the influence of society, he is not completely passive. He understands the environment in which he lives, thinks about it and tries to determine his position in this process. This feature presents the image of the "little man" not as an ordinary and weak human model, but as a person who thinks and tries to understand himself.

At the same time, identity in these works is not presented as a stable concept. It changes over time and is formed in connection with the social environment in which a person lives. This shows that a person's identity depends not only on his inner self, but also on his relationship with society. Social isolation also plays an important role in Baldwin's work. This situation is not only related to a person's alienation from society, but also to changes occurring in his inner world. Isolation often leads to a better understanding of oneself and strengthens one's thinking process.

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PSYCHOLOGICAL SCIENCES

EXAMİNİNG THE RELATİONSHİP BETWEEN LONELİNESS LEVELS AND ARTİFİCİAL INTELLİGENCE SELF-EFFİCACY AMONG UNİVERSİTY STUDENTS

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ÜNİVERSİTE ÖĞRENCİLERİ ARASINDA YALNIZLIK DÜZEYLERİ VE YAPAY ZEKA ÖZ YETERLİLİĞİ ARASINDAKİ İLİŞKİNİN İNCELENMESİ

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Abstract
The aim of this research is to examine the relationship between loneliness levels and artificial intelligence self-efficacy among university students in higher education. 203 students participated in the study, and a correlational survey method was used. The findings reveal significant differences relative to demographic variables.

Özet
Bu araştırmanın amacı yükseköğrenim gören üniversite öğrencilerinin yalnızlık düzeyleri ile yapay zeka öz yeterlikleri arasındaki ilişkiyi incelemektir. Araştırmaya 203 öğrenci katılmış ve ilişkisel tarama yöntemi kullanılmıştır. Elde edilen bulgular demografik değişkenlere oranla anlamlı farkları ortaya koymaktadır.

Keywords: Artificial intelligence, self-efficacy, loneliness, technology, university students, emerging adulthood
Anahtar Kelimeler: Yapay zeka, öz yeterlik, yalnızlık, teknoloji, üniversite öğrencileri, beliren yetişkinlik

Bu araştırmanın temel amacı yüksek öğrenim gören üniversite öğrencilerinin yalnızlık düzeyleri ve yapay zeka öz yeterlikleri arasındaki ilişkiyi incelemektir. Bu araştırmada ek olarak öğrencilerin yapay zeka öz yeterliklerinin demografik değişkenler bakımından anlamlı bir farklılık olup olmadığını belirlemektir. Bu hedefe ulaşabilmek amacıyla da aşağıda verilen alt amaçlar test edilmiştir.

Alt Amaçlar

Üniversite öğrencilerinin yalnızlık düzeyleri ile YZ öz yeterlilikleri arasında olumlu yönde anlamlı bir ilişki var mıdır?

Üniversite öğrencilerinin YZ öz yeterlik düzeyleri cinsiyet, yaş ve sınıf düzeyi değişkenlerine göre anlamlı farklılıklar göstermekte midir?

YÖNTEM

Araştırma Modeli

Bu çalışmada yükseköğretim kurumlarında öğrenim gören öğrencilerin yalnızlık düzeyleri ile yapay zeka öz yeterlikleri arasındaki ilişkinin ne olduğuna yönelik çıkarım yapabilmek amacıyla ilişkisel tarama modelinden yararlanılmıştır.

Araştırmanın Evreni ve Örneklemi

Bu araştırmanın araştırma grubunu Türkiye'de yükseköğretim kurumlarında 2025-2026 eğitim öğretim yılının bahar döneminde öğrenimine devam etmekte olan 116 erkek ve 87 kadın öğrenci oluşturmaktadır.

Veri Toplama Araçları

UCLA yalnızlık ölçeği

Russell, Peplau ve Ferguson (1978) tarafından geliştirilmiş ve Demir (1989) tarafından Türkçeye uyarlanmıştır. Ölçek 20 sorudan oluşmakla birlikte 4'lü likert tipi puanlama sisteminden meydana gelmektedir. Ölçeğin iç tutarlılık katsayısı Cronbach alfa .96 olarak bulunmuş 5 hafta sonra yapılan test-tekrar test katsayısı ise .94 olarak belirtilmiştir (Demir, 1989).

Yapay Zeka Genel Öz Yeterlik Ölçeği kısa formu

Montag (2023) tarafından geliştirilmiş olan ve Türk, Batuk, Kaya ve Yıldırım (2025) tarafından Türkçeye uyarlanmıştır. Ölçek 5 maddeden oluşmaktadır ve 7'li likert tipi şeklinde derecelendirilmiştir. Kullanılan bu ölçeğin Türkçe

uyarlamasının iç tutarlık katsayısı Cronbach alfa değeri .77 olarak belirtilmiştir. Eğer katılımcının ölçekten aldığı puan yüksek ise yapay zeka kullanma becerisinin de o oranda yüksek olduğu belirtilmektedir (Kaya ve ark., 2025).

Verilerin Analizi

Yapılmış olan bu çalışmada bulunan veriler jamovi adı verilen bir istatistik programı aracılığı ile uygun analizler uygulanmıştır. Bu doğrultuda, ilk olarak araştırmaya katılan öğrencilerin demografik özelliklerini belirlemek amacıyla sıklık ve yüzdelik dağılımları hesaplanmıştır. Kullanılan ölçeklerin iç tutarlık katsayısı güvenilir olduğu saptanmıştır. Veriler normal dağılmadığı için Spearman korelasyon analizi yapılmış ve bu doğrultuda geri kalan işlemler non-parametrik analizler ile belirlenmiş ve yapılan bu tüm işlemlerde anlamlılık düzeyi ($p < .05$) kabul edilmiştir.

BULGULAR

Araştırmada yüksek öğrenim gören öğrencilerden alınan bilgiler ışığında betimsel istatistikler, ilişkisel tarama ve parametrik olmayan testler uygulanmıştır. İlk olarak öğrencilerin demografik bilgileri ile ilgili veriler aktarılmış daha sonra öğrencilerin yalnızlık ve YZ öz yeterlilikleri arasındaki ilişkiler incelenmiştir.

Tablo 2

Yalnızlık ve YZ Öz Yeterlik Puanlarının Cinsiyete Göre Mann-Whitney U Sonuçları Tablosu

		Statistic	p
Yaş	Mann-Whitney U	4582	0.254
YALNIZLIK TOPLAM	Mann-Whitney U	3720	0.001
ÖZ YETERLİK TOPLAM	Mann-Whitney U	2656	<.001

Note. $H_a\ \mu_{Erkek} \neq \mu_{Kadın}$

Yukarıda verilen tabloda bu araştırmaya katılmış bulunan öğrencilerin yaş, yalnızlık ve YZ öz yeterlik puanlarının cinsiyete göre anlamlı bir şekilde farklılık gösterip göstermediğini belirlemek amacıyla Mann-Whitney U testinin sonuçlarına yer verilmiştir. Yapılan analizde bu araştırmaya katılan öğrencilerin yaşları, cinsiyet açısından anlamlı bir farklılık söz konusu değildir (U = 4582, p = 0.254). Diğer yandan, araştırmaya katılan öğrencilerin yalnızlık puanları (U = 3720, p = 0.001) ve YZ öz yeterlikleri (U = 2656, p < 0.001) cinsiyet açısından anlamlı bir farklılık gösterdiği elde edilmiştir. Ek olarak, erkeklerin yalnızlık düzeyleri (M = 36.3) ve YZ öz yeterlikleri (M = 29.2) kadın öğrencilere göre (M = 32.4 ve M = 24.6) anlamlı bir biçimde farklılık göstermekte olduğu sonucuna ulaşılmıştır.

Tablo 3

Yalnızlık ve YZ Öz Yeterlik Puanlarının Cinsiyete Göre Betimsel İstatistik Sonuçları

	Group	N	Mean	Median	SD	SE
Yaş	**Erkek**	116	21.7	22.0	2.58	0.239
	Kadın	87	21.4	21.0	2.28	0.244
YALNIZLIK TOPLAM	**Erkek**	116	36.3	37.0	9.03	0.839
	Kadın	87	32.4	31.0	9.33	1.000
ÖZYETERLİK TOPLAM	**Erkek**	116	29.2	30.0	4.77	0.443
	Kadın	87	24.6	25.0	5.57	0.597

Erkeklerin yalnızlık düzeylerinin (M = 36.3) kadınlara kıyasla (M = 32.4) daha yüksek olduğu ve aynı şekilde erkeklerin YZ öz yeterliklerinin de (M = 29.2) yine kadınlara kıyasla daha yüksek olduğu açıkça görülmektedir (M = 24.6).

Tablo 4

Yalnızlık ve YZ Öz Yeterlik Puanları Arasındaki İlişkiye Yönelik Spearman Korelasyon Analizi Sonuçları

		YALNIZLIK TOPLAM	ÖZ YETERLİK TOPLAM
YALNIZLIK TOPLAM	Spearman's rho	—	
	df	—	
	p-value	—	
ÖZ YETERLİK TOPLAM	Spearman's rho	0.023	—
	df	201	—
	p-value	0.745	—

Yukarıda verilen Tablo 4' te üniversite öğrencilerinde yalnızlık ve YZ öz yeterlikleri arasında Spearman Korelasyon Analizi sonuçlarına yer verilmiştir. Yapılan analiz sonucuna bakıldığında bu araştırmaya katılmış olan üniversite öğrencilerinin yalnızlık düzeyleri ve YZ öz yeterlikleri arasında herhangi bir ilişki saptanmamıştır (ρ = 0.023, p = 0.745).

Tablo 5

Yalnızlık ve YZ Öz Yeterlik Puanlarının Sınıf Değişkenine Göre Kruskal Wallis Testi Sonuçları

	χ^2	df	p
ÖZ YETERLİK TOPLAM	14.2	3	0.003
YALNIZLIK TOPLAM	14.6	3	0.002

Yukarıda verilen Tablo 5' te bu çalışmaya katılmış olan öğrencilerin yalnızlık düzeyler ile YZ öz yeterliklerinin sınıf düzeylerine göre farklılık gösterip göstermediğini belirlemek amacıyla yapılmış olan Kruskal Wallis testinin sonuçlarına yer verilmiştir. Yapılan analiz sonuçlarına bakılacak olursa sınıfın hem yalnızlık (χ^2 = 14,6; df = 3; p = 0.002) hem de YZ öz yeterlik (χ^2 = 14,2; df = 3; p = 0.003) değişkenleri üzerinde anlamlı bir etkisi olduğu belirlenmiştir.

Tablo 6

YZ Öz Yeterlik Puanlarının Sınıf Düzeyi Değişkenine Göre İkili Karşılaştırma Analiz Sonuçları

		W	**p**
1.Sınıf	**2.sınıf**	2.031	0.477
1.Sınıf	**3.Sınıf**	1.406	0.753
1.Sınıf	**4.Sınıf**	4.390	0.010
2.sınıf	**3.Sınıf**	-0.500	0.985
2.sınıf	**4.Sınıf**	3.315	0.088
3.Sınıf	**4.Sınıf**	3.697	0.044

Yukarıda verilen Tablo 6'da sınıf düzeyinin YZ öz yeterliği üzerindeki anlamlı etkisini ortaya çıkarmak için ikili karşılaştırma sonuçları verilmiştir. Sonuçlara bakıldığında bu araştırmaya katılıp sınıf düzeyi 4 olan öğrencilerin YZ öz yeterlikleri diğer sınıflara göre daha yüksek olduğu anlaşılmaktadır. Elde edilen bu sonuca göre ise öğrencilerin eğitim-öğretim süreci ilerledikçe YZ ile olan öz yeterlikleri artmıştır.

Tablo 7

Yalnızlık Puanlarının Sınıf Düzeyi Değişkenine Göre İkili Karşılaştırma Analiz Sonuçları

		W	p
1.Sınıf	**2.sınıf**	1.075	0.872
1.Sınıf	**3.Sınıf**	-2.700	0.224
1.Sınıf	**4.Sınıf**	-2.847	0.183
2.sınıf	**3.Sınıf**	-4.561	0.007
2.sınıf	**4.Sınıf**	-4.546	0.007
3.Sınıf	**4.Sınıf**	-0.205	0.999

Yukarıda verilen Tablo 7'de sınıf düzeyinin yalnızlık üzerindeki etkisini ortaya çıkarmak için ikili karşılaştırma sonuçları verilmiştir. Yapılmış olan bu karşılaştırma neticesinde 2. sınıf olan öğrencilerin yalnızlık puanlarının 3. sınıf (W = -4.561, p = 0.007) ve 4. sınıf (W = -4.546, p = 0.007) olan diğer öğrencilere göre daha yüksek olduğu sonucuna varılmıştır. Elde edilen bu analiz sonucuna göre ise öğrencilerin üniversite hayatının ikinci senesinde daha yalnız oldukları veya hissettikleri söylenebilir.

SONUÇ, TARTIŞMA VE ÖNERİLER

Ölçeklerden elde edilen veriler jamovi adında bir istatistik programına aktarılmış ve sıklık, ortalamalar gibi betimsel istatistik araçları hesaplanmıştır. Bunların yanında araştırmada kullanılan iki ölçeğin ilk olarak güvenirlik analizleri yapılmış güvenilir ve geçerli olduğu saptanmış olup bunların yanında değişkenler arasındaki ilişkilerin durumunu göstermek için Mann Whitney U testi, Kruskal Wallis testi ve Spearman Korelasyon analizleri kullanılmıştır. Bu araştırmaya katılan öğrencilerin neredeyse hepsi yapay zeka kullandıklarını belirtmiştir. Araştırmada cinsiyet farkının oldukça önemli olduğu belirlenmiş ve erkeklerin kadınlara oranla daha yalnız oldukları ve aynı zamanda da yapay zeka öz yeterliklerinin de daha fazla olduğu sonucuna ulaşılmıştır. Ek olarak sınıf düzeyinin de oldukça önemli olduğu, sınıf düzeyinin arttıkça yapay zeka öz yeterliklerinin de paralel olarak arttığı sonucuna ulaşılmış olup özellikle 2. sınıf ile olmakla beraber yüksek öğrenim hayatına yeni başlayan öğrencilerin yalnızlık düzeyininde fazla olduğu belirlenmiştir.

Yapılan bu araştırma ile birlikte yükseköğretim kurumlarında öğrenim görmekte olan erkeklerin kadınlara göre daha çok yalnızlık yaşadıkları ve aynı zamanda da yapay zeka öz yeterliklerinin de daha fazla olduğu saptanmıştır. Akyol Güner ve ark. (2022) yapmış oldukları araştırmada ise kadınların benzer şekilde yalnızlıklarının erkeklere oranla daha düşük olduğu sonucuna ulaşmışlardır. Yine başka bir çalışmada ise bilgisayar öz yeterlik algılarının erkeklerde daha fazla olduğu belirtilmektedir (Arslan, 2022). Bu noktada teknolojiye daha kolay uyum sağlamış olan ve teknoloji ile içi içe olup daha çok vakit ayıran kişilerin sosyalleşmeleri azalarak arkadaşlık ilişkilerinin kötüye gideceği ve gittikçe yalnız kalmaya başlayacakları belirtilebilir (Seçim ve ark., 2014).

Alanyazındaki bazı araştırmalar ile ters düşmüş olsa da bu araştırmaya katılan öğrencilerin yalnızlık düzeylerinin yapay zeka öz yeterlikleri arasındaki ilişki incelenmiş ve herhangi bir ilişki bulunmamıştır. Yakın zamanda yapılmış olan bir çalışmada üniversitede öğrenim gören öğrencilerin yalnızlık düzeyleri ile yapay zekaya olan bağımlılıkları arasındaki ilişki incelenmiş olup olumlu yönde ilişki bulunmuştur (İşgör, 2025). Sonuç olarak yapay zeka araçlarını kullanmanın yalnızlık faktörünü azaltmadığını tam tersi yalnızlığı artıran bir faktör olabileceğini ifade etmiş olan araştırmalarla açıklanabilir (Dong, Xie & Gong, 2025; Jacobs, 2024; Xie, Pentina & Hancock, 2023; akt. İşgör, 2025). Araştırma sonuçlarına bakılarak aşağıdaki verilen öneriler uygulanabilir:

1. Daha büyük bir örneklem grubu ile çalışılabilir.
2. Üniversitelerde rehberlik faaliyetleri düzenlenerek özellikle 1. ve 2. sınıf öğrencilerine sosyal uyum ve ait hissetmeleri adına çeşitli etkinlikler yapılabilir.
3. Farklı fakültelerde eğitim gören öğrencilerde çalışmaya dahil edilebilir.
4. eğitim materyalleri geliştirilerek adın öğrencilerin yapay zeka öz yeterliliklerini arttırılabilir.
5. Ele alınan bu konuyu daha derinden incelemek için nitel araştırma yöntemi kullanılabilir.

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SOCIAL SCIENCIES

COVERAGE OF VIOLENCE AGAINST WOMEN ON RUSTAVI 2 (2020-2025)

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Abstract

Violence against women refers to any act of gender-based violence that results in physical, sexual, or psychological harm or suffering to women. This type of violence can take many forms, including but not limited to domestic violence, sexual assault, rape, human trafficking, female genital mutilation, and forced prostitution. It is a widespread and deeply rooted problem that affects women of all ages, backgrounds, and social statuses worldwide.

Ignoring ethical norms when reporting on violence can have significant consequences for both individuals and society as a whole. If the media disseminates incomplete information or misinformation without ethical guidelines, this can lead to public confusion, distrust of media outlets, violation of the presumption of innocence, and the introduction of stigma.

This practice can also violate the law on the inviolability of private life, and sensationalized coverage can cause emotional distress, damage to human reputation, and even physical harm.

The aim of this paper is to reveal the dynamics of media coverage of violence, to demonstrate its transformation trends in this regard, and to promote the introduction of such principles of coverage that do not encourage perpetrators, do not aggravate the situation of family members of victims, do not create new stigma, and do not place the wrong emphasis.

Keywords: violence. Rustavi 2. Coverage. Women. Abusers. Victims. Gender.

Introduction

The main goal of the study is to reveal the dynamics of coverage of violence against women in modern television media, using the example of "Rustavi 2". This will allow us to assess media development and demonstrate trends in coverage of the issue. By identifying positive and negative factors, specific results of the study, the right strategy can be formed. Accordingly, it will help media representatives to correctly cover the facts, maintain balance, and the presumption of innocence. The work will help students of the Faculty of Journalism and researchers interested in the issue. Also, the subject of the study: revealing the dynamics of media coverage of violence against women. The object of the study is the content of "Rustavi 2" for 2020-2025. The aforementioned media organizations were selected for observation based on their ratings, which allow us to analyze the most popular content in the country's media outlets while revealing the dynamics of reporting on violence against women."

Research method: The study used a qualitative research method, with the following techniques: document analysis (content analysis); in-depth/expert interview; case study

Researchers working on the coverage of violence against women focus on various aspects of the issue. They analyze how violence against women is portrayed in the media, examining the imagery, language, images, and narratives used in news coverage. They investigate whether television media perpetuate stereotypes, victim-blaming, or trivializing violence, and how these representations influence public perceptions and attitudes toward gender-based violence. Scholars study the dynamics of media coverage of violence against women, including patterns of agenda setting, news selection, and editorial decisions. They investigate which types of violence receive the most media attention, how coverage differs across media outlets and platforms, and the factors that shape the media agenda on this issue. In her book MEDIA IN PROCESS TRANSFORMATION AND DEMOCRATIC TRANSITION, Osepashvili presents the results of a study on the topic of domestic conflicts in the Georgian media. For this purpose, the author studied the Georgian media of 2011-12. The content analysis method used to conduct the study confirms that family conflicts are mainly caused by domestic violence. The study confirmed that women are the main victims of domestic violence, both from their husbands and children, although they still do not leave the family and avoid talking about violence in public. According to the study, coverage of this topic was low. Georgian media provide basic information about campaigns to combat domestic violence, but there are also numerous cases of sensationalist reporting in which certain facts are exaggerated and journalistic ethical standards are violated. The author of the study offers some recommendations to journalists on how to cover such sensitive and ethical topics so as not to harm the victims

of domestic conflict (in this case, women) and further violate their rights. (https://books.google.ge/, 2017)

Authors Gulchin Akbashi and Susan Seylan-Batur in their work: "Media Coverage of Intimate Partner Violence Against Women" (2023). They draw attention to the fact that the media plays an important role in shaping public perception and understanding of violence against women. It is noted that media messages are characterized by a clear emphasis on female sexual purity and male dominance. The "honor culture" often justifies violence against women in the name of preserving honor. The authors' findings reveal that newspapers are mainly occupied with blaming the victim and justifying the violent behavior of men. In addition, news coverage is often local in scope; the media fails to recognize the need for broader discussion, thereby unintentionally empowering the perpetrator and failing to provide adequate support to the victim (Gülçin Akbaş, 2023)

In her article "Covering Femicide: How Mexican Journalists Struggle to Cover Violence Against Women" (2022), Mariam Hernández draws attention to the fact that in one of the Mexican states, known as one of the most violent places against women, 20 interviews were recorded with journalists who covered femicide cases. He emphasized that individual journalists had only limited knowledge of coverage standards for this issue and consistently sought appropriate ways to report on it without inadvertently encouraging further violence. They also tried to choose the right terminology, using legal forms. The author uses the term "violence against women" in the article and explains that this term should be used when reporting the facts, since violence mainly occurs because of their gender role. (HERNANDES, 2023)

Gunilla Kranz and Ingrid Mogren (2022) state in their report that violence against women is a major public health problem worldwide. Violence against women, whether physical, sexual, or psychological, is more common in countries with low levels of gender equality, high unemployment, and low social cohesion. Some countries have implemented interventions to control violence, for example, by raising awareness about violence against women and human rights in community organizations. Researchers believe that measures need to be taken against men who commit violence against women.

Despite this, the problem may remain unrecognized because women interpret the violence they experience as a normal, everyday part of life or do not know who to turn to for help. Women may also hide the impact of violence due to social stigma. Globally, violence against women also prevents women from participating equally in economic and social life, and as a result, relatively few women hold decision-making positions in society.

For example, Pakistani women, who must raise children, do household chores, and be submissive and obedient to their husbands and families, are restricted by their husbands and in-laws, both in terms of reproductive autonomy and decision-making power.

The authors say that educated women are better off, with more professional careers, but such privileged women are a minority in Pakistan. (https://www.tandfonline.com, 2012)

In her article (2023) titled "Twitter and Misogyny: A Systematic Analysis," Sara Rodriguez examines misogyny (hatred of women) within the social media platform Twitter. The author argues that misogyny extends beyond the offline and into the online environment, which is why she studies the nuances of this issue, patterns of manifestation, user characteristics, and potential violence.

The author identifies 91 relevant articles. The study mainly covers the period from 2015 to 2023, reflecting contemporary trends in misogyny on the social platform.

The study highlights that the premise of violence is often irony, which is directed at women and incites misogyny. It also identifies the types of communities and users who participate in the publication of misogynistic tweets, using various means, Such as memes and hashtags.

The simplicity of the content contributes to the spread of misogyny on Twitter. The author recommends that Twitter, as a social media platform, should play an active role in protecting its users.

Key recommendations include interventions such as: emphasizing positive interactions, filtering personal words, and encouraging structured debate. Legal protection against hate crimes and the promotion of good practices from around the world are also proposed.

(Rodríguez González, 06.08.2023)

Discussion and results

Coverage of women's issues on the example of "Rustavi 2". One of the most watched television channels in Georgia, not only talk shows, but also news programs devote considerable time to covering violence against women. It is noteworthy that Rustavi 2 often adopts a dramatic approach to coverage, although it attempts to exercise caution.

We note that Rustavi 2 often cannot resist the temptation to associate certain perpetrators with political groups or to portray them as well-known individuals who commit crimes. In parallel with this, the perpetrator and the victim are identified, and the fact is covered with a touch of sensationalism. Also, there are harsh assessments of political figures, comments from fans of famous people, etc. This direction does not present the tragedy in its entirety to the viewer but creates the feeling that everything is interesting when the political context is added.

"Rustavi 2" covered the fact of the attack on a transgender woman, Nata Talikishvili, due to which Davit Peradze, number 52 on the parliamentary list of the "Lelo" union, was arrested. It was broadcast on TV that the court had already released him on bail. The investigation established that Nata Talikishvili was verbally and physically assaulted by a man unknown to her; in particular, he hit her on the head with a piece of stone.

The injured person is not in a life-threatening condition. Ana Dolidze's party, "For the People," published a statement on the incident. The political team claims that Davit Peradze left the political union

of his own free will a month ago. It is also noted that they condemn all manifestations of violence.

David Peradze, a member of the coalition “Strong Georgia,” said he pleaded not guilty. "I do not admit guilt, as such, there was no violence. He himself hit me on the hand when I took out my other hand and held it. At that moment, he took out a spray can and sprayed it in my eyes. I hit him on the hand as part of the repulsion. I plan, of course, to file a lawsuit. Ana Dolidze's statement is a withdrawal of support. As for party membership, I did not leave the party of my own free will, but the Election Code required it," states David Peradze. (23.10.2024)

On the air of "Rustavi 2", facts of violence against women committed by famous people are often covered in a specific, sometimes sensational, emotional, and dramatic form. We can highlight several striking features:

The stories often employ an emotional background, a strong tone, and expressive intonation that provokes public indignation. Phrases are used that enhance the drama of the situation. When covering cases, Rustavi 2 often focuses on the famous person himself, his career, and popularity, and not so much on the victim’s history or the systemic side of the problem. The emphasis is often on the image of the famous person and less on how society should prevent similar behavior in the future.

Journalists at Rustavi 2 often adhere to professional standards that create a formal appearance of balance; however, in practice, public sympathy may shift toward the more prominent individual due to their frequent on-screen presence and active self-defense. In this regard, it is noteworthy that journalists subsequently invite a person who has been caught in violence or a confirmed perpetrator to talk shows, again comment on various topics, and again consider him an authoritative person. This is an encouragement to the abuser, in a context where, for example, in America, films even 20 years old featuring actors who have been caught engaging in violence have been removed from theaters, they are not being released on television, and many famous people have had their careers ruined, their image tarnished, and their respect from society diminished for this very reason.

After the coverage, the channel often shows social reactions: comments, posts, and conducts public opinion polls.

This generates discussion and polarization, boosting television ratings; however, it can also hinder empathy toward the victim and distract from the underlying issue.

At the end of the story, the presenter or journalist often makes a general moral remark. For example, statements such as ‘’violence has no justification’’ may be superficial and lack systematic or analytical explanation. For example, why do state institutions fail to respond in a timely manner, and how does media coverage of such cases influence public consciousness?

In this regard, the text does not violate the presumption of innocence, which is one of the main requirements of journalistic ethics. In terms of journalistic standards, the text is quite correct. The source is cited, and the text indicates that Rustavi 2 obtained information from the Ministry of Internal Affairs. This is a reference to a reliable source, which increases accuracy. Despite its neutral tone, the text still focuses on the detainee as an individual (name, surname, nickname, profession).

It would be good practice to focus on the action rather than the person (for example, by using a sentence like this: “A case of violence involving an actor has been investigated”). The text clearly draws attention to the following elements: the name, surname, nickname, and profession are given in the very first sentence (“Georgian actor and rapper Kakha Abuashvili, also known as Kabu”). It focuses on the so-called “celebrity, “increasing audience interest—a strategy frequently employed in media coverage to boost ratings. “They were arrested, “an investigation is underway,” - these phrases inform us of the fact. The statement “The incident took place on the street” provides a clear image for the audience but may also heighten their emotional response.

The text is informative; however, the narrative remains focused on the individual rather than on systemic issues (e.g., rising levels of violence)

The text does not formally violate journalistic standards; however, its personalized focus generates interest primarily because the violence was committed by a so-called “celebrity “. This, in turn, obscures the seriousness of the story.

In 2022, Rustavi 2 extensively covered the case involving the prominent tennis player Nikoloz Basilashvili, who was accused of violence by his ex-wife, Neka Dorokashvili. She said that Basilashvili’s violence was permanent, including when they were still married. Basilashvili’s family denied this information and stated that no violence had taken place. Later, the court confirmed that Nikoloz Basilashvili is innocent, which led to outrage from both the complainant and the public.

The narrative in this case is presented with the following title and concept: “Nikoloz Basilashvili, by the court’s decision, is innocent - according to the assessment of Neli Dorokashvili’s lawyer, this verdict is a step back in the process of women’s rights.”

The information was spread in this form: “The Tbilisi City Court found Nikoloz Basilashvili not guilty. Judge Khatuna Kharchilava announced the final verdict against Nikoloz Basilashvili at the end of the day. The court found the tennis player, who was accused of physical, psychological, and economic violence against his wife, not guilty in all episodes.

The judge provided a detailed explanation of the basis for the acquittal. According to Khatuna Kharchilava, the examined evidence could not prove physical violence against Neli Dorokashvili, as for verbal abuse, according to the judge, the video footage in the case revealed that similar incidents took place on both sides.

After several months of deliberation, the court could not establish the fact of economic violence. The judge also explained in court the evidence on which he based his decision.

Nikoloz Basilashvili is satisfied with the judge's verdict. He says he is innocent, which the court officially confirmed today. The tennis player believes that he is the victim of false accusations by his ex-wife.

The injured party disagrees with the verdict. Neka Dorokashvili did not attend the announcement; however, her lawyers provided an assessment of Judge Khatuna Kharchilava's decision. Human rights activists say that the judge failed to protect the interests of the woman who was the victim of violence. The lawyers requested a guilty verdict and imprisonment for the famous athlete.

The prosecution does not accept the decision. The prosecutor's office will appeal Judge Khatuna Kharchilava's verdict to the Court of Appeal. According to the prosecutor, there was all the evidence in the case for a guilty verdict.

The court set Nikoloz Basilashvili's bail at 100,000 GEL as a preventive measure on May 24. Based on today's acquittal, this amount will be returned to the famous tennis player."

An analysis of the coverage in terms of linguistic, structural, and ethical standards shows that the text is primarily informative, written in a neutral and formal tone, and supported by references to official sources.

However, a degree of bias is evident, particularly in the phrasing and emphasis.

When disseminating the story and information, a factual tone is used - "the court found him not guilty", "the judge explained", "the prosecutor's office will appeal" - which creates the illusion of objectivity, although there are certain emotional elements in the narrative that emphasize Basilashvili's position: "Nikoloz Basilashvili is satisfied", "he believes that he is a victim of false accusation." These formulations strengthen his positive image, which upsets the balance.

Journalistic standards (accuracy, balance, impartiality, ethics) are sometimes respected in the text, sometimes not: both sides are quoted - the position of the defense and the prosecution. Official sources are used (court, prosecutor's office, lawyers).

The following violations are highlighted: Basilashvili's position is clearly distinguished in the text (his emotion, joy, assessment), but the injured party is presented only briefly, through the third person ("she did not attend the announcement of the verdict").

As a result, the viewer may be left with the impression that the case was unfounded from the very beginning and the woman's accusations turned out to be false, which reinforces the gender-biased perception. From a linguistic perspective, the information is formally neutral; however, it also carries an emotional tone that favors Nikoloz Basilashvili."

Journalistic standards are partially respected (both sides are presented, but unequally). There is no sensitive approach to the topic of violence.

A story aired during the study period was devoted to the annual statistics of domestic violence, focusing on what types of violence prevail in the country and where the most cases were detected. ("Rustavi 2" 12-10-2022, 21:30)

The story states that from January 1 to August alone, 5,827 restraining orders have been issued. The number of female victims is more than 4,500, and the number of male victims is only 887. Accordingly, the number of male perpetrators is 5 times higher.

As for the types of violence, according to the Ministry, during the same period, 146 cases of physical violence, 5,382 cases of psychological violence, 119 cases of economic violence, 24 cases of sexual violence, 45 cases of coercion, and 31 cases of neglect were detected in the country. According to the regions, the most cases of domestic violence occurred in Tbilisi.

The Ministry of Internal Affairs has been working for years to prevent femicide. The Deputy Minister explained today what mechanisms the agency has in place to prevent crime.

1. From the stories broadcast in 2020-2025, we analyzed materials that elicited significant public response using a case study approach. The content we studied was dominated by stories from the news program "Kurieri", which focused on the incident.

2. Of the 52 stories analyzed, 38 included detailed depictions of the tragedy aimed at boosting ratings, potentially harming the reputation of the victim or their family. In 20 cases, coverage focused on minor children, incorporating comments and footage from neighbors.

3. In 2020, violations of ethical norms were observed, for example, on the air of the "Comedy Show", where they presented violence "with satire and humor". This case was the last to be included in the Public Defender's report.

4. Among the violations identified was the lack of information about shelter centers and state services, which represents a breach of reporting standards. In recent years (2024–2025), the number of stories addressing state services has increased, and when covering femicide cases, Kurieri has also invited psychologists and human rights defenders to comment, indicating an improvement in journalistic standards.

5. This type of violation was most common, for example, when covering several femicide cases in 2021-2022, journalists made public the victim's house, comments from neighbors who "blamed" her, and did not hesitate to identify children, ignoring Principle 8 of the Charter.

6. Often, the motives for violence in the stories were named as "jealousy" or "love", which romanticized the crime and indirectly "exonerated" the perpetrator. The story focused on the problems of a single family and failed to address the issue as systemic. Dramatic music and footage depicting violence were often used, which only had an emotional impact. In the case of "Rustavi 2", we have the following situation:

7. News programs try to maintain balance, but due to their operational nature, they often make mistakes and do not comply with the law on the inviolability of private life and personal data.

8. The rate of violence in entertainment programs and talk shows is much higher because the victim is often re-traumatized live on air (e.g., confrontation with the perpetrator's family members), as well as

discussion-analysis of the fact, and, in some cases, "justification" for certain reasons.

Summary statistical proportion:

• 70% - informative, standards-compliant coverage.

• 20% - ethical flaws (mainly at the level of displaying visual details and story titles).

• 10% - (possibly unintentional) disclosure of personal data.

Conclusion

Thus, over the past year, especially in 2024-2025, Rustavi 2 has been actively covering facts of violence against women, femicide, preparing stories on sexual and psychological violence, facts of domestic violence, active campaigns against violence by state structures, official statements, and also preparing stories in support of victims. Its language was characterized by an emotional tone, and it also sought to provide information promptly, with varying degrees of dramatization, largely due to the high level of public interest in the case.

Initially, the tendency toward dramatization stems from the channel's positioning as a 'source of exclusive information,' which, in turn, shapes the emotional tone of its coverage. In this direction, it actively works to create public opinion.

The following formulations prevail in the cases: "husband killed his wife", "systematically committed violence", "murder in front of the children", "murder committed by an ex-wife", "physical violence", "aggressive behavior", "murder committed under aggravating circumstances", "bloody separation in the family", "inflicted multiple wounds with a knife", "previously convicted man", "conflictual personality", etc. In some cases, "Rustavi 2" is characterized by strong emotional formulations, the use of evaluative epithets, and an intensification of the dramatic background.

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TECHNICAL SCIENCES

INSTRUCTION FOR THE ESTABLISHMENT AND MAINTENANCE OF THE STATE LEVELLING NETWORK OF THE REPUBLIC OF BULGARIA – UPDATE ADDRESSING TECHNICAL PROBLEMS

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Abstract

The 1st and 2nd order State Levelling Network of Bulgaria provides the foundation for all vertical control in the country during the execution of engineering-geodetic activities related to the economy, infrastructure, investment design, and defense.

The procedures and technical requirements for the establishment, acceptance, maintenance, and updating of the network are governed by Instruction No. RD-02-20-1 of 2021.

This article examines specific technical problems identified within the aforementioned Instruction. It proposes concrete measures to address these challenges via a 'Roadmap' aimed at modernizing the regulatory framework in alignment with current technological trends.

Keywords: State Levelling Network, United European Levelling Network, European Vertical Reference System, 1st order precise levelling, GNSS Levelling, Normal Heights, Kinematic Model.

8. Introduction

The State Levelling Network (SLN) of Bulgaria is a fundamental component of the National Geodetic Infrastructure. By integrating SLN benchmarks into the United European Levelling Network (UELN) and defining them within the European Vertical Reference System (EVRS), a unified vertical datum for the Republic of Bulgaria is established.

In accordance with the Geodesy and Cartography Act, the Geodesy, Cartography and Cadastre Agency (GCCA) has commissioned a phased re-measurement of levelling lines as part of the '5th Cycle of the 1st Order State Levelling Network' since 2021. These operations are conducted pursuant to Instruction No. RD-02-20-1 of January 15, 2021 [1].

Given the critical importance of the SLN for the economy, infrastructure, and defense, strict adherence to technical requirements and methodological standards is essential to ensure the precision and quality of the final data. In this regard, the article analyzes specific technical challenges identified within the current Instruction.

The study is based on a comprehensive review of the SLN for the period 1920–2020, covering the evolution of the regulatory framework, a historical overview of measurement activities, and an analysis of modern methodological approaches in levelling, concluding with recommendations for future development [2, 3].

9. Instruction for the Establishment and Maintenance of the State Leveling Network

Instruction No. RD-02-20-1 of January 15, 2021, on the Establishment and Maintenance of the State Levelling Network (the Instruction) is the primary regulatory act governing the vertical datum of the country. It defines the procedures and technical requirements for the construction and renewal of the 1st and 2nd Order SLN.

The document is organized into nine chapters covering the complete technological cycle:

- General Provisions and Regulatory Framework.
- Core Elements of the SLN: Types of levelling benchmarks.
- Preparation and Design: Field reconnaissance, line design, and numbering.
- Technical Execution: Benchmark stabilization and documentation (benchmarking).
- Measurement Procedures: Instruments and equipment, station methodology, and field quality control.
- Specific Technologies: Gravimetric and GNSS measurements, as well as levelling in special cases.
- Office Data Processing: Network adjustment, precision analysis, and preparation of technical reports.
- Maintenance: Rules for the long-term protection and renewal of the network.

10. Meta-meta Data Level

Although the Instruction is a relatively new document (effective as of February 5, 2021), aimed at modernizing outdated regulations from the preceding socialist period, several key technical problems and challenges remain a subject of discussion within the surveying community.

The most significant technical and practical problems are as follows:

1. Conflict between Vertical Datums - Baltic Vertical Datum 1958 (BVD58) vs. European Vertical Reference System (EVRS)

While not explicitly stated, the Instruction remains heavily tied to BVD58. Simultaneously, as an EU member, Bulgaria has committed to implementing the

EVRS – specifically the EVRF2007 (European Vertical Reference Frame 2007) realization.

- The Problem: Transitioning between these systems is not merely a mathematical transformation but requires extensive re-measurements. The lack of a fully defined transition mechanism within the Instruction creates confusion during the handover of projects of national importance.

2. Integration of GNSS Technologies

The Instruction focuses primarily on classical geometric levelling (utilizing digital levels and invar staffs).

- The Problem: Modern practice relies heavily on GNSS measurements for height determination. However, the Instruction sets extremely high accuracy requirements that are difficult to achieve via GNSS alone without an exceptionally precise quasigeoid model for the territory of Bulgaria. A technological 'gap' exists between traditional methods and modern geodetic theory and practice.

3. Condition of Benchmarks (Physical Network)

The Instruction technically requires measurements to be tied to existing and/or newly established benchmarks of the SLN.

- The Problem: A large portion of the benchmarks (underground and/or wall benchmarks) have been destroyed or damaged over the last 40 years. When surveyors cannot locate benchmarks in the field, they are forced to seek them at great distances, which increases project costs and leads to an accumulation of errors that the Instruction does not tolerate.

4. Tectonic Activity and Data Currency

Bulgaria is situated in a relatively seismically active zone with modern vertical crustal movements that are non-homogeneous across the country.

- The Problem: The Instruction prescribes a Least Squares adjustment methodology that assumes the network is relatively static between update cycles. In reality, the heights of certain benchmarks change by mm annually. Without systematic (every 10–15 years) comprehensive re-measurement of 1st and 2nd order SLN benchmarks, the data in the State Geodetic, Cartographic, and Cadastral Fund (Geocartfund) becomes technically problematic.

5. Lack of Detail in Digital Processing

While allowing the use of digital levels, the Instruction does not provide exhaustive details regarding the standards for digital records (raw data) that must be archived.

- The Problem: Different adjustment software packages utilize varying weighting models and processing algorithms, which occasionally results in minimal but legally significant discrepancies in adjusted heights from identical input data.

In summary: Overall, the Instruction is a positive step forward, but it remains a fundamentally 'conservative' document. It prioritizes the reliability of classical methods, which sometimes conflicts with the dynamics of modern construction and digital geodesy..

11. Proposed amendments to address the technical problems of Instruction No. RD-02-20-1

To resolve the technical problems of the Instruction and transform it into a document aligned with the current state of the technological field, several fundamental changes are required. If we were to 'rewrite' it today, the focus must shift from viewing Geodesy solely through the eyepiece of a level to perceiving it through the lens of sensors and Big Data.

Here are the specific steps for a potential technical optimization:

1. Full Integration of GNSS Levelling

Instead of treating GNSS as an 'auxiliary' or 'secondary' method, the Instruction should officially regulate hybrid levelling.

- Proposed Change: Define a methodology for determining normal heights through direct GNSS measurements and the application of a high-precision National Quasigeoid Model.
- Result: Surveyors will be legally permitted to utilize GNSS for vertical control in a broader range of projects, provided they adhere to strictly defined quality control protocols.

2. Transition from Static to Kinematic Models (4D Geodesy)

The Earth's crust is in constant motion, and the Instruction must legally acknowledge this reality.

- Proposed Change: Introduce the concept of a reference epoch. The height of a benchmark should no longer be a simple scalar H, but a function of time:

$$H(t) = H_0 + v(t - t_0)$$

where: $H(t)$ is the reference normal height for epoch t; H_0 is the reference normal height for epoch t_0 and v is the vertical velocity of the specific region for the time interval $(t - t_0)$.

- Result: This resolves the issue of 'subsiding' or 'uplifting' benchmarks in seismic zones, ensuring that 1st and 2nd order SLN data remains reliable and current for years.

3. Final Adoption of the European Vertical Reference System (EVRS)

It is time for the definitive decommissioning of the obsolete Baltic Vertical Datum.

- Proposed Change: The Instruction must establish a clear timeline for the transition to EVRF2019 (or the latest European framework). This includes publishing official transformation parameters between the old Baltic system and the new European system for every node in the network.
- Result: Full compatibility with European infrastructure projects and an end to 'double accounting' in height applications.

4. Digitalization of Raw Data and Implementation of a Raw Data Standard

- Proposed Change: Require the mandatory submission of digital instrument records in a standardized format (e.g., LandXML or GML), rather than merely final calculated normal heights in PDF or Excel tables.
- Result: The Geodesy, Cartography and Cadastre Agency (GCCA) will be able to automate measurement quality checks and detect errors, moving away from relying on the contractor’s 'good faith'.

5. 'Active' Benchmarks and Virtual Networks

Physical benchmarks are vulnerable to destruction or deformation.

- Proposed Change: The Instruction should include permanent GNSS infrastructure stations as primary nodes of the SLN. These stations act as 'living' benchmarks whose heights are monitored 24/7.
- Result: Even if all physical benchmarks in a city are destroyed, the vertical datum can be instantly restored through the corresponding permanent GNSS station.

Technical Evolution Summary:

Current State (Instruction RD-02-20-1)	Future Solution
Focus on geometric levelling	Hybrid methods (GNSS + Geoid)
Static heights (no time component)	Kinematic model (velocity fields)
Baltic Vertical Datum (Local)	EVRS (Pan-European)
Paper/PDF protocols	Machine-readable formats (XML/JSON)

12. Why is the transition from a static to a kinematic model important?

In the context of modern geodesy, transitioning from a static to a kinematic model is the correct approach for the following two reasons:

1. The Definition of Kinematics

In Physics and Geodesy, kinematics studies the motion of objects (position, velocity, acceleration) without considering the forces that cause it. By incorporating time and the rate of vertical displacement into the normal height, we describe the purely geometric movement of the Earth's crust. This is a classic kinematic approach.

2. International Standards

All modern reference systems, such as the International Terrestrial Reference Frame (ITRF), are defined as kinematic frames. They recognize that tectonic plates are in motion and provide coordinates for a specific epoch alongside velocity vectors. Aligning the Regulation's logic with this principle would be inherently "kinematic."

Comparison between Static and Kinematic Models:

Model	Description	Mathematical Component	Applicability in Instruction № RD-02-20-1
Static	Position at a specific moment	H (constant)	Current state (obsolete)
Kinematic	Motion (geometry + time)	H + velocity*time	The correct choice for the future

13. Conclusion

To overcome bureaucratic inertia (the "administrative dragon") and technical challenges, the transition to a kinematic model and the modernization of Instruction № RD-02-20-1 must be implemented in stages. It is crucial to emphasize that this is not a sudden overhaul, but the cultivation of an ecosystem designed to make the transition seamless and almost invisible to the end user.

Below is a concrete roadmap for implementing these changes:

1. Establishing a National Vertical Velocity Model

Before requiring surveyors to calculate time epochs, the state (via the GCCA) must provide the necessary infrastructure.

- Implementation: A map of vertical crustal movements across Bulgaria will be developed based on long-term data from permanent GNSS stations and historical leveling records.
- Outcome: Surveyors will have localized data—for instance, knowing that the Varna region (East Central Bulgaria) is subsiding at υ mm/year, while the Rhodope Mountains (South Central Bulgaria) are rising.

2. Developing an "Official Height Calculator" Web Service

To prevent practitioners from having to solve complex equations manually, the state should implement an accessible online Web Service.

- Implementation: The GCCA provides an API or web interface where users enter the benchmark ID, measurement date, and observed height. The system automatically reduces the value to the reference epoch (e.g., 2026.0) using the national velocity model.
- Outcome: The administration receives standardized datasets, and surveyors are spared manual computation.

3. "Hybrid" Phase for Regulation № RD-02-20-1

The regulation should allow for a dual-method approach during a transitional period (e.g., 5 years).

- Implementation: Use of GNSS is authorized for 4th-class National Leveling Network (NLN) surveys and establishing geodetic control, provided that an approved "Digital Quasigeoid Model" for the territory of Bulgaria is utilized.
- Outcome: This discourages the fabrication of "paper-only" leveling traverses (a practice born from the difficulty of locating destroyed physical benchmarks) and legitimizes modern field practices.

4. Implementing "Digital Passports" for NLN Benchmarks

Physical benchmarks must have a digital twin in the cloud.

- Implementation: Every NLN benchmark will be assigned mandatory metadata in the GCCA information system, including the last measurement date, accuracy metrics, site photos, and time-series displacement graphs.
- Outcome: If a surveyor or designer sees that a benchmark hasn't been verified in 30 years, they can

instantly gauge its low reliability, and the system will suggest a more stable alternative.

How would the workflow look after the change?

Action	Current (Issues)	Future (Optimized)
Reference Selection	Searching for a physical benchmark (which may be destroyed).	Use of the nearest GNSS station + local benchmark.
Measurement	Labor-intensive geometric leveling over relatively long distances or leveling lines.	GNSS measurement with control at a given benchmark from the National Leveling Network (I & II class).
Processing	Manual adjustment without accounting for subsidence.	Automatic reduction to epoch via web service.
Submission	PDF report and paper folder.	XML/GML file that directly updates the database.

The most effective way to demonstrate the value of the proposed changes is through the implementation of pilot projects in 'challenging' regions—such as Northeast Bulgaria (with its active landslides) or the Sofia Basin. If the model proves successful there by saving time and reducing errors, the administration will have concrete proof that the change is a practical solution rather than a 'theoretical exoticism.'

In the Republic of Bulgaria, in accordance with the theory adopted from the Soviet scientist Molodensky, normal heights H_γ are utilized, where the reference surface is the quasigeoid rather than the geoid. The distinction between the two is significant, particularly in mountainous regions, where the 'geoid–quasigeoid' separation can reach several decimeters.

This fact must be integrated into future amendments of Instruction No. RD-02-20-1 through the prism of a kinematic model for normal heights:

1. Transition to a "Dynamic Quasigeoid"

When discussing a kinematic model for normal heights, we must actively monitor changes in height anomalies (ζ).

- Technical Amendment: Instruction No. RD-02-20-1 should mandate the maintenance of a time-dependent quasi-geoid model. Since the quasi-geoid surface depends on mass distribution and the gravity field, any fluctuations (tectonic, hydrological) alter the value of ζ.
- Height Formula at Epoch t:

$$H_\gamma(t) = h(t) - \zeta(t)$$

where: $h(t)$ is the ellipsoidal height (from GNSS) and $\zeta(t)$ is the height anomaly from the dynamic quasigeoid model.

2. Kinematics of Normal Heights and Gravimetry

Since normal heights are based on the normal gravity field but calculated through actual leveling measurements, they are directly linked to the gravity potential.

- The Issue: Vertical crustal movements (uplift or subsidence) also alter the local gravity field.
- Regulatory Change: A requirement for periodic absolute gravimetric measurements at the reference points of the State Leveling Network (SLN) should be established. This will enable the kinematic model to account for both geometric displacement and changes in the potential field that defines the quasi-geoid.

3. GIS Visualization and Infrastructure

From a geoinformation perspective, the quasi-geoid is a surface that "breathes."

- Integration: Instead of a static grid of ζ values, the state should provide a 4D quasi-geoid surface. GIS software must be capable of interpolating the ζ value for specific coordinates (X,Y) at a specific time t.
- Metadata: The digital passport of every benchmark must explicitly state: "Height type – Normal; Quasigeoid reference epoch – 202X.X."

Technical Architecture Summary for the Modernization of Instruction No. RD-02-20-1:

Element	Current State	Target State (considering Normal Heights)
Reference Surface	Quasigeoid (static)	Quasigeoid (kinematic/dynamic)
Height Type	Normal	Normal with velocity vector
Transformation	Tables/Corrections	4D Height Anomaly Model
Measurement Method	Geometric leveling	Hybrid (GNSS + Precise Quasigeoid + Leveling)

Key takeaway: The emphasis on normal heights ensures that the Bulgarian geodetic tradition is enhanced with modern technologies without compromising its theoretical precision.

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HOW DO DEEP LEARNING-BASED FACE RECOGNITION SYSTEMS ADDRESS CURRENT CHALLENGES THROUGH DIFFERENT DATA MODALITIES AND EVALUATION APPROACHES

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Abstract

Deep learning has been widely used in solving the various challenges that are encountered in the field of face recognition. Pose variations, illumination changes, aging of the individual whose face is being recognized, and changes in the spectral distribution of the images of the faces all pose challenges for recognition systems. To combat these issues, various modalities of facial data have been incorporated into face recognition systems. The different data types that are used in deep learning for face recognition include RGB data, 3D facial data, video data, near-infrared (NIR) data, and synthetic data. RGB data is the most common modality used for face recognition, but other modalities are often incorporated into address specific recognition challenges. Commonly used deep learning models in face recognition include convolutional neural networks (CNNs), ResNets, and VGG models. Additionally, various innovations to these models have been developed, such as using different data augmentations specific to the task of face recognition, fusing features from different data types, creating new types of loss functions, such as ArcFace, and using attention mechanisms. Recognition models that use multiple data types and address spectral variations tend to experience improvements in recognition rates of between 0.5% and over 15%. Additionally, recent developments in face recognition that address issues such as data privacy, robustness against adversarial attacks, and fairness among different demographics highlight the shift towards holistic and ethical solutions for face recognition. The integration of diverse data types into deep learning models for face recognition and the use of diverse evaluation methodologies to test these models are crucial elements in overcoming the various challenges that are experienced within the field of deep learning and face recognition.

Keywords: Face Recognition, Deep Learning, Multimodal Data, Cross-Spectral Recognition, Evaluation Metrics

I. INTRODUCTION

Given the importance of social media platforms, mobile authentication, and security systems, facial recognition technology has evolved into a fundamental technology in the modern world. Despite the great progress that has been made in the creation of facial recognition systems, these systems are still vulnerable to many problems, such as changes in facial posture, illumination, expression, occlusion, and ageing effects [2]. Furthermore, differences in recognition performance according to age, gender, and ethnicity of the individuals whose faces are to be recognized are well recorded in the technical literature. There is, therefore, a desperate need for techniques that are more inclusive of all demographics in facial recognition. Current research on facial recognition systems demonstrates that there can be performance differences of as much as 25% between different demographic groups. Although deep learning techniques, specifically convolutional neural networks (CNNs) have largely taken over the technology and methodologies of the older, hand-crafted feature methods for facial recognition, these deep learning systems are also still vulnerable to the same problems noted above, especially in unrestricted environments in the real world.

To overcome these noted limitations of current facial recognition systems, researchers have turned to the use of multimodal data inputs to their facial recognition systems. Multimodal data can include synthetic data to increase the robustness of the recognition systems, three-dimensional (3D) scans of the faces to be recognized, near-infrared (NIR) images of the faces, and RGB images of the faces that incorporate depth maps. As an example, using both RGB and depth maps or using NIR and visible (VIS) spectral images has allowed for increases in the accuracy of facial recognition systems in challenging environmental conditions. Furthermore, the use of domain-specific data augmentation methods, loss functions such as ArcFace, and attention mechanisms have provided additional enhancements in the performance of facial recognition systems on many benchmark datasets.

Many studies have been performed on the topic of deep learning–based facial recognition, but most of these studies have focused only on using single-modality inputs and on the use of comparatively small datasets to train the deep learning models of these facial recognition systems, and without considering the implications of the use of multimodal data inputs and evaluation methods in these systems [9]. Thus, there is a need for a survey of the existing literature in this area of study, with the aim of providing an up-to-date and complete overview of the topic.

The aim of this survey is to provide a complete and up-to-date overview of the various data modalities and evaluation methods for deep learning–based facial recognition systems. Specifically, the survey will aim to review the performance of multimodal facial recognition systems, what challenges still exist within the current state of the technology, and the suggestions for potential solutions to those challenges.

II. REVIEW METHODOLOGY

The methodology behind this survey is inspired by the guidelines established by the PRISMA research initiative to ensure the reproducibility of this research. The main stages of the research consisted of searching for relevant literature, screening and selecting relevant literature, determining eligibility based on literature screening results, and extracting data from the included literature studies.

A. Literature Search

A literature search was conducted in order to gather information regarding peer-reviewed scientific publications that relate to the topic of deep learning–based face recognition. More specifically, each of the research studies was to be reviewed according to each of the following categories: the types of modality that were used within the publication (such as RGB, RGB-D/3D, NIR–VIS, thermal, video, and synthetic modalities), and the methods by which the studies were evaluated (such as if they performed verification, identification, or open-set evaluation methods). Each of the databases that was searched included IEEE Xplore, ScienceDirect, SpringerLink, and Semantic Scholar, each of which have numerous journals and conferences related to the field of computer vision and biometrics (such as the IEEE Transactions on Pattern Analysis and Machine Intelligence, the IEEE Transactions on Information Forensics and Security, the Conference on Computer Vision and Pattern Recognition, the IEEE Conference on Computer Vision and Pattern Recognition, and the International Journal of Biometrics). Each of the publications that were searched were those that were published between January 2018 and February 2026, with the search being performed on February 20, 2026.

In order to guide the literature review of the database publications, there were three main components to the search strategy: the type of model that was used in each of the reviewed scientific publications, the task that was to be performed by the model within each of those publications, and the terms related to the modality and evaluation of the models that were utilized within each of those publications. Each of these terms were refined through the performance of search pilot tests to ensure that they would maximize the number of relevant scientific publications that would be retrieved in response to the search terms, while minimizing the number of non-relevant scientific publications that would be retrieved. Additionally, some adaptations were made to the search terms in each individual database to ensure that they were appropriately defined within that particular database and publisher. The resulting base search terms for the literature review are presented below:

(“deep learning” OR CNN OR transformer OR “deep neural network”)

AND (“face recognition”)

AND (“RGB” OR “RGB-D” OR “3D face” OR “NIR-VIS” OR thermal OR “cross-spectral” OR video OR synthetic)

AND (verification OR identification OR “open-set” OR benchmark OR protocol)

The inclusion criteria for studies to be included in this review are defined as follows. First, the studies must use deep learning methods to perform face recognition (not merely detection). Second, the studies must be evaluated on one or more public datasets. Finally, the studies must report quantitative results according to some defined protocol. Studies that are excluded include those that are survey papers, not peer-reviewed publications, do not include experimental validation of their methods, and those that focus solely upon peripheral tasks to face recognition. The search results from the databases were exported and merged, then processed to remove any duplicates. The remaining records had their titles and abstracts screened to determine whether they potentially relate to the topic of deep learning face recognition. Those papers whose full texts were obtained were screened again to determine whether they satisfied the inclusion criteria. The process for selecting the studies for inclusion was inspired by the PRISMA framework, and a quality checklist for research studies was applied during later stages of the review. The search strategy and study selection process may be obtained upon request.

B. Screening and Selection

Following the completion of the database search, all the records retrieved during the search were exported and merged into a single dataset. Duplicates were removed using both automatic and manual processes. As a result of these steps, 82 duplicate records were removed from the dataset, leaving with 453 unique records for screening.

These screening steps were conducted according to the PRISMA guidelines. Screening of titles and abstracts revealed that 333 of the records did not meet the objectives of the proposed research. These records were excluded during the first round of screening for the following reasons: they did not include studies of face recognition tasks (n=97), deep learning methodologies (n=65), multimodal or evaluation studies (n=71), studies that focused solely upon detection methods (n=54), or studies that did not include any quantitative evaluation of the performance of the methods proposed and implemented in the studies (n=46).

As a result of the screening of titles and abstracts, 120 articles were selected for further screening according to the defined inclusion and exclusion criteria. The inclusion criteria for these articles required that the studies include the use of deep learning methods for the performance of face recognition, that they were evaluated upon one or more publicly available datasets, and that they published quantitative results from such evaluations. Exclusion criteria for these articles required that the studies not perform any experimental evaluations of their methods, that they not publish evaluation protocols or metrics, that they not use publicly available datasets for evaluation, and that their methods not relate to tasks other than face recognition.

Both inclusion and exclusion criteria were applied to ensure that the screening of articles for inclusion in the review was both reproducible and unbiased. Any studies that were found to be ambiguous according to these criteria were examined in whole to ensure that they met the criteria for inclusion in the review. Fig. 1 presents a high-level overview of the article screening

process that was performed to select these articles for inclusion in the review.

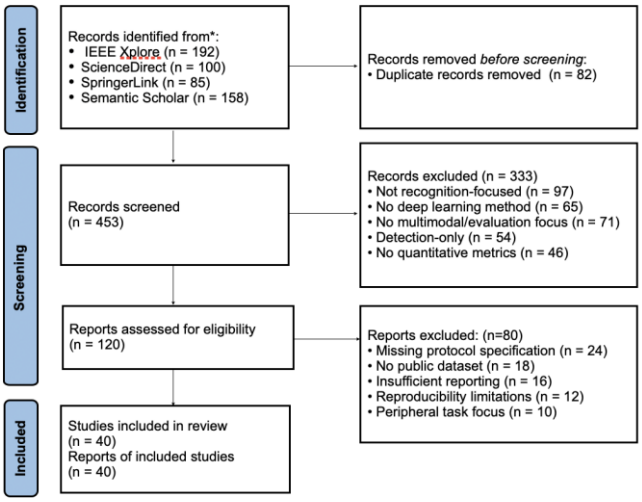
Identification
Records identified from*:
• IEEE Xplore (n = 192)
• ScienceDirect (n = 100)
• SpringerLink (n = 85)
• Semantic Scholar (n = 158)
Records removed before screening:
• Duplicate records removed (n = 82)
Screening
Records screened
(n = 453)
Records excluded (n = 333)
• Not recognition-focused (n = 97)
• No deep learning method (n = 65)
• No multimodal/evaluation focus (n = 71)
• Detection-only (n = 54)
• No quantitative metrics (n = 46)
Reports assessed for eligibility
(n = 120)
Reports excluded: (n=80)
• Missing protocol specification (n = 24)
• No public dataset (n = 18)
• Insufficient reporting (n = 16)
• Reproducibility limitations (n = 12)
• Peripheral task focus (n = 10)
Included
Studies included in review
(n = 40)
Reports of included studies
(n = 40)

Fig1. PRISMA 2020 flow diagram illustrating the study selection process.

C. Full-Text Eligibility Assessment

The inclusion of the remaining 120 articles was performed through assessing their full texts to ensure that the studies met the required criteria for the study. Each of these articles was assessed more deeply than those that were screened for their titles and abstracts.

Each study was assessed against a structured set of eligibility criteria. Specifically, papers were required to:

(i) clearly define the face recognition task (verification, identification, or open-set recognition),

(ii) evaluate performance on publicly available or sufficiently described datasets,

(iii) explicitly report evaluation protocols (e.g., LFW 10-fold verification, IJB-C TEST-4 open-set protocol),

(iv) provide quantitative performance metrics such as Rank-1 accuracy, TAR@FAR, DIR@FPIR, or EER, and

(v) describe model architecture and experimental settings with sufficient detail to enable interpretation.

The following inclusion and exclusion criteria were applied to determine which studies would be utilized in the review: studies would be excluded if they did not have a protocol, metrics, dataset, experimentation, or if they were focused on tasks other than those that recognized the benchmarking of peripheral tasks.

During this stage, 80 articles were excluded from the review. The main reasons for exclusion included missing evaluation protocol ($n \approx 24$), missing datasets ($n \approx 18$), missing quantitative results ($n \approx 16$), missing experimental details ($n \approx 12$), and focus on tasks other than evaluation of recognition methods ($n \approx 10$). These articles were excluded according to the distribution of articles represented in the PRISMA diagram.

Additionally, other borderline studies were reviewed to ensure they met the same criteria as the studies that had already been excluded. All studies that did not meet the criteria were excluded at this stage.

As a result of this screening process, 40 studies were included in the review according to all the defined inclusion criteria.

D. Data Extraction

In order to compare the various studies that were selected for the review, a table was developed that enabled the studies to be systematically compared with one another. The framework for the table ensured that each study would be reviewed with the same questions to facilitate the comparison of each study.

For each of the 40 included studies, the following information was extracted:

- Publication details: authors, year, and venue
- Modality type: RGB, RGB-D, 3D, NIR–VIS, Thermal–VIS, or hybrid
- Model characteristics: network architecture (e.g., CNN, ResNet variants, transformer-based), loss function design, and training strategy
- Fusion strategy (if applicable): early fusion, intermediate/attention-based fusion, late fusion, or shared embedding space
- Dataset(s) used: including dataset name and scale (e.g., LFW, MegaFace, IJB-B/C, CASIA NIR–VIS 2.0)
- Evaluation protocol: verification, identification, or open-set recognition, including protocol variants where specified
- Performance metrics: Rank-1 accuracy, TAR@FAR, DIR@FPIR, EER, or other reported metrics
- Reported results: exact quantitative values, including improvements over baselines where available
- Experimental conditions: such as cross-spectral evaluation, pose variation, occlusion, low-resolution settings, or adversarial scenarios
- Reported strengths and limitations: as discussed by the original authors

In order to ensure the comparability of the extracted results, certain standardizations were made regarding the datasets from which the results were reported. For instance, all verification results from the LFW dataset used the 10-fold protocol, while the results from IJB-C were reported according to the TAR@FAR or open-set evaluation protocols stated in

the respective articles. Similarly, any reported improvements in recognition rates also referenced the datasets upon which those improvements were measured.

The extracted results were organized into tables (Tables I-IV) according to the types of evaluations performed by each method. The main groupings included methods that used only RGB images, those that utilized both RGB and depth information (RGB-D) or 3D models, methods that utilized images of different spectral types, and the reliability of the methods. These tables allowed for easy comparison of the various methods according to their performance on the evaluated metrics.

E. Study Quality Assessment

In order to ensure the reliability and comparability of the studies that are included in this review, they will be assessed for their quality. Such an assessment will aim to determine the performance of the study in addition to the quality of its methods.

Each paper was evaluated across four key dimensions:

1. Protocol Transparency
   - ○ Clear specification of evaluation protocol (e.g., LFW 10-fold verification, IJB-C TAR@FAR thresholds, open-set TEST protocols)
   - ○ Explicit definition of evaluation metrics and thresholds
2. Dataset Transparency
   - ○ Use of publicly available benchmark datasets
   - ○ Clear description of dataset splits, training/testing configurations, and experimental conditions
3. Quantitative Reporting
   - ○ Reporting of exact numerical performance values (e.g., Rank-1, TAR@FAR, EER)
   - ○ Inclusion of baseline comparisons or ablation studies to support claimed improvements
4. Reproducibility Indicators
   - ○ Availability of implementation details (architecture, training setup, hyperparameters)
   - ○ Reporting of training data sources and experimental configurations
   - ○ Code availability or sufficient methodological description

Each of these dimensions was assessed for the level of reported completeness within each study – studies lacking clarity in two or more of these dimensions were interpreted with caution when comparing their results to one another.

This quality assessment was applied to all papers included in this study. While the quality of the studies was not used to exclude any studies during this initial stage of the investigation, their results were utilized to provide context for the research papers' reported results.

Through performing the assessment of the quality of the research papers published during the time period investigated, performance can be better contextualized for readers rather than providing a simple presentation of the results published in each of the tables.

III. Results

Table I.

Performance Comparison of Deep RGB-Based Face Recognition Architectures

Ref	Modality	Dataset(s)	Protocol	Metric(s)	Key Result
[1]	RGB	LFW; MegaFace	Verif.; Ident.	Rank-1; TAR@FAR	99.73% (LFW); 97.67% TAR@1e−6 (MegaFace)
[2]	RGB	LFW; MegaFace; IJB-C	Verif.; Ident.	Rank-1; TAR@FAR	99.83% (LFW); 94.88% Rank-1 (MegaFace 1M)
[3]	RGB	IJB-B; IJB-C	Verif.	TAR@1e−4	97.64% (IJB-C)
[4]	RGB	IJB-B; IJB-C	Verif.	TAR@1e−4	97.80% (IJB-C)
[5]	RGB	IJB-C; LFW	Verif.	TAR@1e−4	96.80% (IJB-C)
[6]	RGB	IJB-C; MS1M	Verif.; Ident.	TAR@1e−4	97.23% (IJB-C)
[7]	RGB	MegaFace; LFW	Ident.; Verif.	Rank-1	98.50% Rank-1 (MegaFace)
[8]	RGB	IJB-B; IJB-C	Verif.	TAR@FAR	+3.5% (IJB-B, vs. baseline)
[9]	RGB	IJB-C; LFW	Verif.	Rank-1	Improved few-shot performance
[10]	RGB (Low-Res)	IJB-C; TinyFace	Ident.	Rank-1	Significant gain (low-resolution setting)

Analytical Evaluation of RGB-Based Architectures

The improvements in the face recognition literature based on RGB images are the result of developing new margin-based loss functions, not because of the changes to the architecture of the deep neural networks. The loss functions that were used previously with softmax layers have been replaced with new margin-based loss functions such as ArcFace that encourage the deep neural networks to create embeddings that are more separable across different identity classes and compact within the same class. This has greatly improved the TAR@FAR rates on databases like IJB-B and IJB-C.

As summarized in Table I, the RGB-based methods published from 2018 onwards include a variety of loss functions and training strategies. On controlled benchmarks such as LFW and MegaFace, these approaches rapidly saturated near-perfect verification accuracy (>99.7% on LFW), suggesting that closed-set frontal face recognition under constrained conditions is largely a solved problem. However, more challenging datasets such as IJB-B and IJB-C provide stronger dif-

ferentiation among methods. For example, Ref. [4] reports 97.80% TAR@1e−4 on IJB-C compared to 97.64% in Ref. [3], representing a 0.16% absolute improvement under identical protocol settings. Although numerically small, such gains are meaningful in low false-acceptance regimes critical for high-security deployments.

Further improvements are made possible with curriculum learning, adaptive margin strategies, and various scalable training mechanisms such as Partial FC for handling extremely large identity sets. The results of these approaches allow for models to generalize well to different pose variations. Despite these improvements, however, the gains in recognition rates on IJB-C among the latest RGB-only models still generally remain in the range of 0.5% to 2%, and sometimes even drop to below 0.2%.

Scalability and data dependence are two main characteristics of RGB-based approaches. The performance of RGB-based approaches relies on the availability of large-scale training data such as MS1M and MegaFace to achieve high Rank-1 and TAR metrics. However, RGB-based approaches suffer from a range of domain shifts, including changes in the resolution of the captured facial images such as those in the TinyFace dataset. While increasing the resolution of the training data improves the performance of RGB-based approaches, the lack of other types of information, such as geometric information, limits the potential of RGB-based approaches to learn representations that are robust to challenging conditions. Overall, RGB-based approaches are the most scalable and readily deployable biometrics solutions. However, their limitations in terms of robustness provide motivation for the alternatives that will be presented in the following sections of this paper.

Table II.

Multimodal RGB-D and 3D Face Recognition Approaches

Ref	Modality	Fusion Type	Dataset(s)	Protocol	Metric(s)	Key Result
[11]	RGB →Depth	Hallucination	CurtinFaces	Ident.	Rank-1	+3–5% (vs. RGB baseline)
[12]	RGB + Depth	Intermediate (Attention)	CurtinFaces; IIIT-D RGB-D	Ident.	Rank-1	>99% (IIIT-D)
[13]	RGB + Depth	Hybrid Feature-Level	Lock3DFace	Ident.	Rank-1	SOTA (hybrid fusion)
[14]	RGB + 3D	Dual-Stream CNN	Bosphorus 3D	Ident.	EER	98%
[15]	Thermal + VIS	Shared Embedding	TUFTS	Verif.	Rank-1	Reduced cross-spectral gap
[16]	RGB + NIR	Coupled Deep Learning	CASIA NIR-VIS 2.0	Ident.	Rank-1	Cross-modal gain
[17]	RGB + NIR	Domain-Invariant Embedding	CASIA NIR-VIS 2.0	Ident.	Rank-1	Improved invariance
[18]	RGB + Depth	Progressive Multi-Modal	CurtinFaces	Ident.	Rank-1	Outperformed unimodal RGB

Analytical Evaluation of Multimodal RGB-D and 3D Approaches

The approaches summarized in Table II indicate that the improvements in recognition accuracy over RGB-only methods are primarily achieved through the integration of geometric and depth information into the approach, rather than through the use of embedding-loss refinements alone. While the RGB methods discussed in the table primarily utilized angular-margin optimization strategies, the multimodal approaches instead introduced structural modifications to the methods, such as using dual-stream encoders or fusing the embeddings through attention mechanisms. Finally, the methods that employ hallucination-based approaches to generating depth maps for the images still achieve moderate improvements in recognition accuracy, with improvements of around 3-5% on datasets like CurtinFaces. Attention-driven intermediate fusion models achieve strong performance on IIIT-D RGB-D (>99% Rank-1), suggesting that adaptive modality weighting enhances discriminative representation under controlled RGB-D conditions. Similarly, dual-stream RGB+3D networks evaluated on Bosphorus 3D report identification accuracy around 98%, reflecting improved robustness to pose variation and geometric deformation.

However, the magnitude of the improvement is also relative to the size of the dataset used to evaluate these methods. For instance, the size of most of the RGB-D datasets is still significantly smaller than the size of the largest RGB dataset. Thus, the gains in accuracy of these methods on relatively small datasets may not necessarily translate to gains in the accuracy of these methods on large-scale facial recognition systems. Furthermore, there are a variety of additional constraints that are associated with implementing these multimodal methods, including the cost of specialized hardware to capture both RGB and depth data simultaneously, the synchronization of those two data streams,

the computational cost of utilizing two separate encoders to process the RGB and depth data, and the availability of large datasets of multimodal facial data to appropriately train these systems.

While multimodal approaches exhibit stronger robustness to various conditions that adversely impact RGB methods, their scalability is limited compared to RGB methods trained on millions of identities. Consequently, while such methods are robust against pose, illumination, and occlusion variations, their limitations in terms of scalability suggest that they are only suitable for applications where robustness is an important property—such as security applications—rather than for general use as a scalable replacement for RGB-based models.

Table III.

Cross-Spectral Face Recognition (NIR–VIS and Thermal–VIS)

Ref	Spectral Pair	Method Type	Dataset	Protocol	Metric	Reported Performance
[19]	NIR–VIS	Hallucination + Embedding	CASIA NIR-VIS 2.0	10-fold Ident.	Rank-1	96.41%
[20]	NIR–VIS	Coupled Feature Learning	CASIA NIR-VIS 2.0	Ident.	Rank-1	75–90% range
[21]	NIR–VIS	Domain Adaptation	CASIA NIR-VIS 2.0	Verif.	Rank-1	Improved via adaptation
[22]	NIR–VIS	Relation-Based Embedding	CASIA NIR-VIS 2.0	Ident.	VR@FAR=0.1%	Significant gain
[23]	Thermal–VIS	Deep Perceptual Mapping	TUFTS	Verif.	EER	Reduced error rate
[24]	NIR–VIS	Multi-Modal Learning	CASIA NIR-VIS 2.0	Ident.	Rank-1	Multi-modal learning improves cross-spectral recognition

Analytical Evaluation of Cross -Spectral Recognition

Cross-spectral face recognition remains significantly more challenging than unimodal RGB recognition due to the substantial domain gap between modalities. As summarized in Table III, most approaches are evaluated on CASIA NIR–VIS 2.0 using either 10-fold identification or verification protocols, with performance typically reported as Rank-1 accuracy or VR@FAR.

The method based on hallucination ([19]) obtains 96.41% Rank-1 on the CASIA NIR-VIS 2.0 dataset by first hallucinating visible light images from the near-infrared (NIR) inputs and then learning embeddings from the visible light images. Thus, the method indicates that image translation and learning embeddings can reduce the impact of spectral discrepancies. However, the inclusion of this hallucination step increases the complexity of the model and may have a negative impact upon recognition of synthesized images.

The coupled feature learning methods ([20]) report Rank-1 results between 75% and 90%. Though simpler than the models that use hallucination, the coupled feature learning methods are more dependent upon the feature space and may have difficulties handling large illumination or pose variations.

Domain adaptation strategies ([21]) aim to minimize the distribution mismatch between NIR and VIS domains at the feature level. Although the results of these methods demonstrate some improvements in recognition accuracy, their performance is still affected by the bias and diversity of the training datasets.

Relation-based embedding approaches ([22]) demonstrate significant improvements under verification protocols (e.g., VR@FAR=0.1%). These methods leverage relational modeling between spectral pairs, improving discrimination under strict FAR constraints. This is particularly important for security-critical applications, where low FAR performance is prioritized over raw Rank-1 accuracy.

Thermal–VIS recognition on TUFTS ([23]) demonstrates reduced error rates for verification metrics (EER). However, thermal–visible recognition exhibits lower performance than NIR–VIS settings.

From a protocol perspective, most studies employ the Rank-1 protocol to identify the face identities, while relatively few use protocols that evaluate the verification performance at low FARs. Thus, these studies cannot be readily compared with the results from the existing large-scale RGB database benchmarks, such as IJB-C.

In summary:

• Hallucination methods show the highest Rank-1 performance on CASIA NIR–VIS 2.0.

• Domain adaptation and relation-based embeddings improve robustness under verification constraints.

• Thermal–VIS recognition remains less mature compared to NIR–VIS.

• Most evaluations are dataset-specific and lack large-scale open-set testing.

Table IV.

Reliability and Security in Face Recognition: Fairness, Adversarial Robustness, and Open-Set Recognition

Ref	Evaluation Type	Dataset	Protocol	Metric	Key Finding
[25]	Fairness	RFW	Verif.	TAR disparity	Reduced ethnic gap
[26]	Fairness	MORPH; RFW	Verif.	FMR/FNMR	Age & race bias observed
[27]	Fairness	RFW	Verif.	Error gap	Quantified subgroup imbalance
[28]	Fairness	RFW	Verif.	Rank-1 per subgroup	Cross-race drop observed
[29]	Fairness	FairFace	Classification	Accuracy gap	Dataset balance affects bias
[30]	Fairness	FRVT	Verif.	FMR disparity	Demographic error variation
[31]	Adversarial	LFW	Verif.	Accuracy under FGSM/PGD	Significant drop
[32]	Adversarial	LFW	Verif.	Robust accuracy	Geometric perturbation impact
[33]	Adversarial	IJB-C	Verif.	TAR@FAR	Robustness reduced under attack
[34]	Adversarial	IJB-C	Ident.	Rank-1	Patch attack degradation
[35]	Adversarial	IJB-C	Verif.	TAR	Improved via robust training
[36]	Open-Set	IJB-C	Open-Set Ident.	DIR@FAR	Improved unknown rejection
[37]	Open-Set	IJB-C	Open-Set	TPIR@FPIR	Improved detection
[38]	Open-Set	LFW; IJB-C	Open-Set	Rank-1; DIR	Ensemble improves OSR
[39]	Open-Set	IJB-C	Open-Set	Known/Unknown accuracy	Standard benchmark
[40]	Open-Set	IJB-C	Open-Set	Extreme Value Modeling	Better threshold calibration

Analytical Evaluation of Reliability and Deployment-Oriented Research

Table IV presents a synthesis of research addressing the reliability of face recognition systems. Despite the high levels of recognition accuracy that deep learning algorithms can achieve on databases such as LFW and IJB-C, the studies indicate that the accuracy of these systems declines significantly when any of the aforementioned reliability factors are introduced.

The remaining studies that focus on the concept of fairness in the literature, from works [[25]-[30]], reveal differences in the performance of face verification systems according to race, age, and gender. The evaluation of systems like RFW and MORPH reveal differences in TAR, FMR, and FNMR according to race, age, and gender groups. Furthermore, while the use of mitigation strategies helps to reduce the disparity between these different groups in relation to verification system performance, there is still a trade-off between fairness and accuracy of the systems. Finally, these studies indicate that the balance of the data set can also have an impact upon the fairness of the verification system, indicating that the composition of the training data has a dominant effect upon the fairness of the system.

Adversarial robustness studies [31]–[35] reveal that deep learning models with high classification accuracies are vulnerable to gradient and patch attacks. The performance degradation of these models is evident under both verification and identification protocols, especially under white-box attacks. While robust training techniques improve the TAR of deep learning models under adversarial attacks, the improvement in robustness usually comes at the cost of accuracy on non-adversarial inputs. Furthermore, there is a lack of consistency in evaluating the robustness of deep learning models in the literature.

Open-set recognition research ([36]–[40]) addresses the practical requirement of rejecting unknown identities. Performance is typically measured using DIR@FAR, TPIR@FPIR, or extreme value modeling approaches. Ensemble methods and calibrated thresholding strategies improve unknown rejection rates, yet open-set performance remains substantially lower than

closed-set identification accuracy. These findings confirm that identity rejection remains a critical weakness of deployed systems.

Table IV collectively illustrates the plateaued progress in accuracy of the existing algorithms yet the continued challenge in ensuring fairness, security, and the ability to handle identities that are yet to be defined within the research. Currently, the progress that has been made in this area is promising yet fragmented, suggesting the need for a standard evaluation of fairness, security, and identity recognition within the proposed algorithms.

IV. Discussion

The comparison across RGB, multimodal, cross-spectral, and reliability-focused directions exposes an architectural tipping point in deep learning-based face recognition. Whereas RGB-only architectures have reached near-saturation for performance on the controlled LFW and MegaFace benchmarks, progress on unconstrained data (e.g., IJB-C) has been progressively harder to come by. Absolute improvements on recent SOTA results for the same evaluation protocol may be less than 1%, and in some cases less than 0.2%, implying diminishing returns on the architecture alone.

While the RGB-D and 3D systems are clearly superior to the RGB systems in some ways, those results can only be partially relied upon. The vast majority of these systems have been evaluated on much smaller datasets than the largest RGB datasets (such as IJB-C). Thus, although the multimodal systems may have been proven superior to the unimodal systems in closed datasets, the scalability and generalizability of those systems on a much larger and more diverse population of individuals and images has yet to be proven. Furthermore, the sensor and computational system requirements of these models, along with their scarcity, present additional issues to their deployment beyond their performance on image recognition tasks.

Another significant problem is the challenge of cross-spectral recognition. Unlike the challenge of cross-modality recognition, where modality-invariant features are learned to overcome the distribution difference of the modality, hallucination-based, domain-adaptation-based, and relation-aware methods are used for cross-spectral recognition. Despite these methods, cross-spectral recognition still trails behind RGB results. Furthermore, the need for paired training data and the evaluation of the models on specific datasets indicate that cross-spectral recognition is still an open problem in the field.

Beyond accuracy, other research studies expose the weaknesses of existing face recognition systems. Studies on the issue of fairness for facial recognition systems show disparities in the performance of the system based on different demographic groups. Adversarial facial recognition attack studies show that the systems have a degradation of the recognition rate when subjected to adversarial attacks. Studies on open-set recognition expose the ways in which facial recognition systems can improve at rejecting unknown identities, though the accuracy of recognizing those unknown identities remains significantly lower than recognizing known identities. Overall, then, these studies show that high accuracy does not necessarily indicate that a facial recognition system is ready for deployment.

A key structural limitation across the field is evaluation fragmentation. Studies report performance using heterogeneous metrics (Rank-1, TAR@FAR at varying thresholds, DIR@FAR, EER), limiting direct cross-study comparability. Moreover, fairness, robustness, and open-set reliability are typically evaluated in isolation rather than within unified multi-objective frameworks. As a result, improvements in one dimension may introduce regressions in another without systematic quantification.

In the future, there is a need for unified evaluation protocols to assess the recognition accuracy, demographic fairness, robustness against adversarial examples, and open-set reliability of face recognition systems. Instead of solely focusing on the incremental improvement of the margin loss function, researchers should focus on learning representation that is invariant to different image modalities, finding multi-objective optimization strategies for the face recognition problem, and developing large-scale benchmark datasets for evaluating face recognition systems. Only through the integration of evaluation and system design can the field of face recognition advance beyond current benchmark evaluations toward robust and reliable systems.

Key Observations

Based on the tables presented above, it becomes evident that there are certain patterns to recognize within the current state of deep learning-based face recognition.

Observation 1: RGB recognition has likely reached performance saturation on current RGB recognition benchmarks. Despite the gains from margin-based loss functions on LFW and IJB-C, there are limited opportunities for further performance improvements on these benchmarks. Future improvements on RGB recognition are more likely to come from improving model robustness and generalization rather than refining the embedding space using margin-based losses.

Observation 2: Multimodal Fusion Shows Promise but Lacks Large-Scale Validation Results. Current RGB-D and 3D methods outperform the RGB approaches under certain conditions. However, there is a lack of validation of these results on a large-scale multimodal benchmark such as IJB. Additionally, the sensor dependency of these approaches limits their feasibility for deployment.

Observation 3: Cross-Spectral Recognition is an Open Challenge. Unlike RGB-D fusion, cross-spectral recognition has to deal with the intrinsic gaps between the data modalities. Although there has been some success with learning representations that are invariant to modality, the variability in recognition performance and the need to use paired training data indicate that this problem is still an open one.

Observation 4: Reliability Dimensions Expose Structural Weaknesses. The three dimensions of fairness, adversarial robustness and open-set recognition reveal the structural weaknesses of a model that scores highly on accuracy in closed-set recognition but poorly on these other dimensions.

Observation 5: Evaluation Fragmentation Limits Cross-Study Comparability. Inconsistent reporting of metrics (Rank-1, TAR@FAR at varying thresholds, DIR@FAR) complicates direct comparison across modalities. The field lacks unified evaluation standards that jointly assess accuracy, fairness, robustness, and open-set stability.

V. Global Limitations of Current Face Recognition Research

Despite the notable advancements in deep learning-based face recognition approaches, there are still a few limitations within the field.

First, the inconsistency in evaluation protocols hinders the comparability of results from different studies. Many studies use different evaluation measures such as Rank-1 accuracy, TAR@FAR, DIR@FAR, and 10-fold cross-validation. As a result, it is difficult to compare the methods from different facial recognition modalities. Furthermore, the performance improvements seen by some methods over others are specific to the datasets used and cannot be generalized.

Second, there is a significant imbalance in the datasets used to evaluate the different categories of facial recognition approaches. For example, RGB-based approaches are evaluated on very large datasets such as IJB-C and MegaFace. In contrast, other approaches involving other sensors use much smaller datasets.

Third, most research in the field focuses on the development and evaluation of close-set systems. Real-world applications will have to deal with situations involving unknown identities, names, demographics, and adversarial perturbations of facial features. Furthermore, the evaluation of robustness and fairness in facial recognition systems is generally performed separately from one another, which makes it difficult to evaluate the system in relation to a real-world scenario.

Fourth, there is a lack of research into the trade-offs between robustness and accuracy in facial recognition systems. Most techniques that improve the model's robustness toward adversarial attacks or demographic fairness suffer a reduction in accuracy on datasets with clean facial images.

Finally, most current facial recognition benchmarks do not incorporate key factors that are considered during the development of facial recognition systems for real-world applications. Thus, there is still a gap between the evaluation protocols established for research studies and those that need to be implemented in real-world facial recognition systems.

To overcome these limitations, it is crucial to develop standardized evaluation protocols, larger multimodal benchmarks, frameworks to evaluate robustness and fairness simultaneously, and representation learning models that maximize both accuracy and reliability of deep learning-based facial recognition systems.

VI. Research Directions

The synthesis of RGB, multimodal, cross-spectral, and reliability-oriented research highlights several strategic directions necessary for advancing face recognition systems beyond benchmark saturation.

1. Unified Multi-Objective Optimization Frameworks

Future research should aim to develop training frameworks that optimize several of these metrics simultaneously. Currently, each of these metrics is often optimized separately from one another; future research, however, should aim to find training frameworks that optimize for accuracy, fairness, robustness, and open-set recognition simultaneously.

2. Standardized Evaluation Protocols Across Modalities

The field requires harmonized reporting standards to enable cross-study comparability. Future benchmarks should define fixed FAR thresholds, unified open-set evaluation protocols, and demographic subgroup reporting requirements. Establishing standardized multi-dimensional evaluation suites—combining Rank-1, TAR@FAR, DIR, EER, and fairness disparity metrics—would significantly enhance reproducibility and interpretability.

3. Large-Scale Multimodal and Cross-Spectral Benchmarks

While several publicly available RGB datasets have benefitted from the large-scale collections of unconstrained images, the availability of multimodal and cross-spectral datasets has been more limited. Future efforts in creating new datasets should aim to provide diverse samples in terms of pose, illumination, demographics, and modality. Additionally, there is a need for large-scale multimodal datasets akin to the IJB-C dataset.

4. Robust Modality-Invariant Representation Learning

The challenge of cross-spectral recognition is still present. Future approaches to this problem can employ transformers to learn cross-domain attention mechanisms, utilize self-supervised methods to align across spectrums, or use generative models to ensure the consistency of the learned representations across domains. Furthermore, domain generalization methods may provide more robust solutions to the problem than supervised training alone.

5. Open-World and Long-Tail Recognition Modeling

It is crucial to consider the long-tail distribution of identities and the changing nature of face galleries in the real world. Future research should focus on integrating incremental learning into face recognition systems. For open-set recognition, it is essential to move beyond the threshold-based approach to recognizing faces and instead model the confidence of the recognition system as part of the learning process of the representation of faces.

6. Deployment-Aware Design Constraints

Most current research is performed under laboratory conditions. Future research should consider the constraints of deployment, such as latency, memory, privacy-preserving training, and sensor variability. To bridge the existing gap, it is essential to consider the impact of performance, efficiency, and privacy.

VII. Conclusion

This paper provided a survey of the literature on deep learning–based face recognition systems, focusing

on four main research directions: RGB-based methods, RGB-D and 3D methods, cross-spectral methods, and methods that consider the reliability of the recognition systems. Specifically, 40 studies were reviewed to provide an understanding of each of these research directions and to map the field of deep learning–based face recognition systems.

The results of the survey indicate that RGB-based methods have approached saturation in their improvements to recognition accuracy. Other methods, such as those using RGB-D and 3D data or that incorporate cross-spectral analysis, are still developing as research directions but have the potential to overcome some of the issues in RGB-based methods. Finally, most of the reviewed methods that considered reliability factors such as fairness, robustness, and open-set recognition demonstrated a gap between accuracy and reliability, indicating a current issue within the field.

Overall, the research within the field is shifting from mainly aiming to improve recognition accuracy to aiming to improve the reliability of those methods. Future research and development in the field will likely shift towards creating standardized evaluation protocols, creating large-scale multimodal datasets, and creating a unified framework for learning face recognition models that improve accuracy, robustness, fairness, and open-set recognition. Filling this gap will enable the creation of trustworthy and deployable face recognition systems.

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EXPERIMENTAL MODELING OF ENERGY FLOW AND SYSTEM PLATFORMS

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Abstract

Energy flow constitutes a fundamental dimension of modern engineering systems, encompassing power grids, renewable energy networks, industrial infrastructures, and cyber-physical platforms. As these systems become increasingly complex due to digitalization, decentralization, and the integration of intelligent technologies, there is a growing need for advanced methods to analyze, predict, and optimize their behavior.

This study explores the conceptual foundations and practical methodologies of experimental modeling, emphasizing its role in capturing the nonlinear, multi-scale, and adaptive characteristics of contemporary energy systems. Particular attention is given to system platforms that integrate physical components (such as energy generation and storage units), data acquisition technologies (including sensors and monitoring systems), and advanced analytics (such as machine learning and real-time optimization algorithms). These platforms facilitate the creation of digital twins and simulation environments, allowing for precise experimentation, scenario analysis, and performance evaluation.

Furthermore, the article highlights key applications of experimental modeling in areas such as smart grids, renewable energy integration, energy-efficient buildings, and intelligent transportation systems. It also discusses current challenges, including data heterogeneity, system complexity, and the need for scalable and cost-effective solutions. By addressing these issues, experimental modeling contributes to the development of resilient, efficient, and sustainable energy systems.

Overall, this research underscores the significance of integrating experimental approaches with digital technologies to enhance decision-making, improve system reliability, and support the transition toward a more sustainable and energy-efficient future.

Keywords: energy flow, experimental modeling, system platforms, smart grids, sustainability

Introduction

In contemporary science and engineering, energy systems are becoming increasingly complex due to the rapid integration of renewable energy sources, digital technologies, and distributed infrastructures. The transition from centralized power generation to decentralized and intelligent energy networks-such as smart grids and microgrids has significantly transformed the architecture and functionality of modern energy systems. This transformation is driven by the growing demand for sustainability, energy efficiency, and resilience in the face of global challenges such as climate change and resource scarcity (International Energy Agency, 2023).

A critical aspect of this transformation is understanding how energy flows within and across interconnected systems. Energy flow analysis involves examining the processes of generation, transmission, distribution, storage, and consumption, all of which are influenced by both physical and digital factors. In increasingly digitized environments, energy systems are no longer purely physical; they are hybrid structures that combine hardware with software, data analytics, and automated control systems. This convergence has given rise to cyber-physical energy systems, where real-time data and intelligent algorithms play a key role in optimizing performance and ensuring system stability (United Nations, 2015).

Given this complexity, traditional analytical approaches are often insufficient to fully capture the dynamic and nonlinear behavior of modern energy systems. As a result, experimental modeling has emerged as a vital methodological tool. It allows researchers and engineers to simulate real-world conditions, test hypotheses, and evaluate system performance within controlled and repeatable environments. By combining theoretical models with empirical data, experimental modeling enhances the accuracy and reliability of system analysis (Blanchard & Fabrycky, 2011).

Moreover, experimental modeling supports innovation by enabling the development and validation of new technologies before their large-scale implementation. For instance, in renewable energy systems, it facilitates the assessment of integration strategies, storage solutions, and demand-response mechanisms. In smart grid applications, it allows for the testing of control algorithms, communication protocols, and fault detection systems under various operational scenarios (International Energy Agency, 2023).

In addition, the emergence of digital platforms-such as simulation environments, digital twins, and data-driven optimization tools has significantly expanded the capabilities of experimental modeling. These platforms enable real-time monitoring, predictive analysis, and adaptive control, thereby improving system efficiency and resilience. As highlighted in global sustainability frameworks, the integration of advanced modeling techniques is essential for achieving long-term energy security and environmental sustainability (United Nations, 2015).

In summary, the increasing complexity of modern energy systems necessitates advanced analytical and experimental approaches. Experimental modeling provides a comprehensive framework for understanding

energy flow dynamics, optimizing system performance, and supporting the transition toward sustainable and intelligent energy infrastructures.

Component	Description	Example
Generation	Production of energy from various sources	Solar panels, wind turbines
Transmission	Transfer of energy over long distances	Power lines, pipelines
Distribution	Delivery of energy to end users	Local grids
Storage	Accumulation of energy for later use	Batteries, hydrogen storage
Consumption	Final use of energy	Households, industries

In cyber-physical systems, energy flow is closely linked with **information flow**, where sensors collect data, and algorithms optimize system performance in real time. This integration is essential for achieving efficiency, flexibility, and sustainability (United Nations, 2015).

Experimental Modeling: Definition and Importance

Experimental modeling is an interdisciplinary research approach that integrates theoretical analysis with empirical experimentation. It involves constructing either physical prototypes or virtual simulation environments to observe system behavior under controlled conditions. This approach is particularly crucial in energy systems, where complexity and uncertainty often limit purely theoretical methods (Blanchard & Fabrycky, 2011).

Unlike purely computational modeling, experimental modeling provides real-world validation, enabling researchers to test assumptions and refine models based on observed data. It is especially valuable in emerging fields such as renewable energy integration, smart grids, and intelligent energy management systems.

Table 2.

Advantages of Experimental Modeling in Energy Systems

Advantage	Explanation
Validation of theories	Confirms accuracy of mathematical and computational models
Identification of inefficiencies	Reveals energy losses and system bottlenecks
Innovation support	Enables testing of new technologies and solutions
Risk reduction	Minimizes failures before large-scale implementation
Real-time analysis	Allows observation of dynamic system behavior

Furthermore, experimental modeling facilitates scenario analysis, where different operational conditions (e.g., peak demand, system faults) can be simulated. This helps in designing more resilient and adaptive systems (International Energy Agency, 2023).

System Platforms for Energy Flow Modeling (Expanded)

Modern energy systems rely on integrated system platforms that combine hardware infrastructure with advanced software tools. These platforms enable comprehensive modeling, monitoring, and control of energy flow processes. They are essential for managing the increasing complexity of decentralized and digitized energy systems.

Key components of such platforms include:

- Simulation environments (e.g., MATLAB/Simulink, digital twins) for predictive modeling
- Sensor networks for continuous data collection and monitoring
- Control systems for automated and adaptive regulation
- Data analytics tools for optimization, forecasting, and decision-making

These platforms form the backbone of cyber-physical energy systems, where physical processes are tightly integrated with computational intelligence.

Component	Function	Example Tools/Technologies
Simulation systems	Model and predict system behavior	MATLAB, Simulink, Digital Twins
Sensors	Collect real-time operational data	IoT devices, smart meters
Control systems	Regulate system processes dynamically	SCADA, automated controllers
Data analytics	Analyze data for optimization and forecasting	AI, machine learning algorithms

The integration of these components enables real-time monitoring and control, supports predictive maintenance, enhances energy efficiency, and improves overall system resilience. Furthermore, digital platforms facilitate the development of smart grids and

intelligent energy networks, which play a crucial role in achieving sustainable development goals (United Nations, 2015).

Methodology of Experimental Modeling

The experimental modeling process generally involves several interconnected stages. It begins with problem definition, where the objectives of the system and its constraints are clearly identified. This is followed by model development, during which mathematical or computational models are constructed to represent the system. The next stage involves designing the experimental setup, which may include either physical prototypes or virtual simulation environments. Subsequently, data collection is carried out by measuring key system variables and performance indicators. The obtained results are then analyzed and validated through comparison with theoretical predictions. Finally, the process concludes with optimization, aimed at improving system efficiency, reliability, and overall performance.

Applications

Experimental modeling of energy flow is widely applied across various domains. It plays a significant role in renewable energy systems, including solar, wind, and hybrid technologies, as well as in the development and operation of smart grids and microgrids. In addition, it is extensively used in industrial energy management systems to enhance efficiency and reduce losses. The approach is also relevant in transportation systems, particularly in the optimization of electric vehicles, and in the field of building energy efficiency, where it supports the design and management of smart homes.

7. Challenges and Future Directions (Expanded)

Despite its significant advantages, experimental modeling of energy flow faces a number of complex challenges that limit its widespread implementation and scalability. One of the primary issues is the high cost associated with designing and maintaining experimental setups, particularly when dealing with large-scale or high-fidelity systems that require advanced hardware, sensors, and simulation infrastructures. In addition, modern energy systems are inherently multi-scale and nonlinear, involving interactions across physical, digital, and socio-economic layers. This complexity makes it difficult to construct models that accurately capture all relevant dynamics without oversimplification. Another major challenge lies in the integration of heterogeneous data sources, as energy systems often rely on diverse datasets generated from different technologies, formats, and time scales. Ensuring data compatibility, quality, and synchronization remains a critical concern. Furthermore, the effective implementation of experimental modeling requires sophisticated computational tools and high-performance computing resources, which may not always be accessible or cost-effective.

Looking ahead, future research in this field is expected to focus on the development of more advanced and integrated solutions. In particular, the emergence of digital twin technology offers new opportunities for creating real-time, virtual representations of physical systems, enabling continuous monitoring, simulation, and optimization. The integration of artificial intelligence and machine learning techniques is also anticipated to enhance modeling accuracy, predictive capabilities, and decision-making processes. Additionally, there is growing interest in the design of real-time adaptive control systems that can respond dynamically to changing conditions and uncertainties within energy networks. Another important direction involves the development of sustainable and energy-efficient system platforms that minimize environmental impact while maximizing operational performance. These advancements align with global priorities for sustainable development and energy transition, as emphasized by international frameworks such as those proposed by the United Nations (2015).

Conclusion

Experimental modeling of energy flow and system platforms plays a pivotal role in the advancement of modern energy systems, particularly in an era characterized by rapid technological change, increasing energy demand, and growing environmental concerns. By effectively integrating theoretical frameworks with practical experimentation, this approach enables a deeper understanding of complex system dynamics, facilitating more accurate analysis, improved system design, and optimized operational performance. It allows researchers and engineers to test innovative solutions in controlled environments, reduce uncertainties, and ensure the reliability and safety of large-scale implementations.

Moreover, experimental modeling contributes significantly to enhancing energy efficiency and promoting sustainable practices by identifying system inefficiencies, minimizing energy losses, and supporting the integration of renewable energy sources. Through the use of advanced system platforms—such as digital twins, real-time monitoring systems, and data-driven optimization tools—it becomes possible to achieve higher levels of automation, adaptability, and resilience in energy infrastructures. These capabilities are particularly important in the context of smart grids, intelligent transportation systems, and energy-efficient buildings.

As global energy systems continue to evolve, driven by digitalization, decentralization, and the transition toward low-carbon economies, the importance of experimental modeling will only increase. Future developments in artificial intelligence, machine learning, and high-performance computing are expected to further enhance the precision and applicability of this approach. In addition, interdisciplinary collaboration between engineering, data science, and environmental studies will play a key role in addressing emerging challenges.

In this context, experimental modeling is not merely a technical tool but a strategic framework that supports innovation, informs policy-making, and contributes to achieving long-term sustainability goals.

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ALTERNATIVE TO THE EXISTING METHOD OF DETERMINATION PARAMETERS OF THE ELECTRICAL CIRCUIT FOR TESTING DEVICES FOR ULTIMATE SWITCHING CAPACITY

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Abstract

At present, there is a method for determining the parameters of an electrical circuit for testing devices for maximum switching capacity by processing oscillograms of changes in time of phase currents. This method provides for the need for the operator to perform graphic operations on oscillograms to determine the power factor. It is necessary to draw two envelope lines along the amplitude values of the phase current and draw the average between them by envelopes line. Along the middle line, the values of the constant components of the current necessary for the calculation are determined. cosφ . Since the nature of the change in time of phase currents depends on the time of the current occurrence in the circuit, there is an ambiguity in the results of calculating the values of the circuit parameters. The error in measuring the circuit parameters also arises from the different qualifications of the operator when processing oscillograms.

Taking into account the above analysis of the existing method, an alternative method for determining the parameters of the circuit has been developed, in which the conditions and results of the calculation of the parameters do not depend on the moment of current occurrence in the circuit. In addition, the developed method does not provide for any participation of personnel in the process of calculating the parameters - the calculation is carried out according to a simple algorithm by a microprocessor device.

From a scientific point of view, the proposed method is based on the analysis not of the dependence of the change in time of the phase current, but of two other dependencies of the change in time, the nature of which does not depend on the moment of occurrence of the disturbance of the circuit. The peculiarities of the nature of these functions make it possible to determine the value of the current from discrete power values measured 5 and 15 ms after the occurrence of the current cosφ. And from the value of the force function measured 16 ms after the occurrence of the current, it is possible to determine the effective value of the phase current.

The peculiarities of the nature of these functions make it possible to determine the value of .cosφ And by the value of the force function, measured 16 ms after the current originated, determine the effective value of the phase current.

Keywords: ultimate switching capacity, test circuit, power factor, force function, power.

1. Introduction

Problem Status for Determining the Parameters of the Electrical Circuit for Testing Apparatus

At present, the regulatory documents, for example, in [1], present a method for determining the parameters of an electrical circuit for testing devices for the Ultimate Short-Circuit Breaking Capacity (I_{cu}), based on the analysis of phase current changes. This method is implemented by taking an oscillogram of the change of currents in the phases $i_a = f(t)$, $i_b = f(t)$ and $i_c = f(t)$. The effective value of the current is determined by oscillograms after the attenuation of the aperiodic component of the current. The value of the power factor (cosφ) is determined by the degree of attenuation of the aperiodic component of the current. For this purpose, the values of the constant components of the current are determined on the oscillogram, determined by the curve passing in the middle between the envelopes of the amplitudes of the current. In this case, the operator must choose for calculations the phase where the aperiodic component of the current, in his opinion, is the largest. The nature of the dependence in time of the current in the phase depends on the moment of current origination. This means that the error in measuring the value cosφdue to the dependence both on the moment of current occurrence and on the qualification of the operator can be quite significantTaking into account the analysis of the existing method for calculating the parameters of the circuit, which we will conventionally call classical, it seems quite urgent to develop a new alternative method. In the new method, there should be no negative impact on the quality of parameter calculations both depending on the moment of current occurrence and the qualification of the operator.

Therefore, the purpose of the work, the results of which are presented in this article, is to develop a method alternative to the classical one, in which graphic and other operator operations are not required to determine the parameters of the test circuit for testing devices for switching capacity. which shall not depend on the moment of disturbance of the electrical circuit. At the same time, the nature of these dependencies must depend significantly on the value of the power factor (cosφ). For this, it is necessary that in the steady-state mode the values of these dependencies must be constant. Such a requirement, for example, corresponds to the dependence of the change in time of direct current. Therefore, the nature of the change in direct current in the transient mode depends only on the value of the time constant. But the nature of the change in the value of the alternating current over time does not meet the above requirement.

However, this does not mean that for AC circuits there are no other parameters and their dependencies of

changes in time that meet the requirements that ensure independence from the moment of the circuit disturbance. To determine what these functions are, it is necessary to consider the entire system of generation and transmission of three-phase current as a whole. In this system, the constant in value is the force on the shaft of the generator and its power. These two parameters, which are constant in magnitude over time, are then divided into three variable magnitude constituents.. But in the receiver, the sum of forces and powers will be constant values. This means that the total active power of all three phases and the function characterizing the change in time of the sum of the forces in all three phases (proportional to the square of the values of the currents) will be constant in the steady-state mode. $p(t)$.For the convenience of further presentation, the last dependence is designated as the force function of the electric circuit -*F(t).*

Taking into account the above analysis,the goal of this work is to develop and substantiate a method for determining the parameters of the test circuit, free from the shortcomings of the classical approach and suitable for full automation based on microprocessor facilities.

2. ***Theoretical foundations of an alternative method for determining the parameters of the test network***

An alternative method for determining the parameters of the test circuit is based on the peculiarities of the nature of the active power of the network and its force function in the transient mode.

2.1 Characteristics of the Time-Varying Nature of Total instantaneous Power.

The instantaneous power of a single-phase electric circuit connected to an inductive load is described by the following expression:

$$p(t) = U_m sin\,(\omega t + \psi) \cdot I_m[\sin(\omega t + \psi - \varphi) - \sin(\psi - \varphi)\, e^{-\frac{t}{\tau}}] \quad (1),$$

where U_m and I_m — are the amplitude values of *the phase voltage and current; ψ — is the random initial phase of the voltage, characterizing the instant at which the disturbance occurs; φ — is the system phase angle of the circuit; and τ— is the electromagnetic time constant of the electrical circuit, related to the angle φ by the expression ωτ=tgφ.*

The formula for the total instantaneous power of a three-phase system can be written as follows:

$$P(t) = \sum_{k=0}^{2} U_m sin\,(\omega t + \psi - k2\pi/3) \cdot I_m[sin(\omega t + \psi - k2\pi/3 - \varphi) - sin(\psi - k2\pi/3 - \varphi)\, e^{-\frac{t}{\tau}}] \quad (2)$$

The time variation of the total instantaneous power of the three phases, $P(t)$—following simple yet rather cumbersome transformations—is described by the following expression:

$$p(t) = 1.5\, U_m I_m[cos(\varphi) - cos(\omega t + \varphi)e^{-t/\tau}] \quad (3)$$

An analysis of expression (3) reveals that the behavior of the function p(t) from the onset of the transient process, takes the form of damped oscillations relative to the steady-state value. It should be noted that expression (3) contains no components with a frequency of f = 2ω, as these mutually cancel out within the total power. This result of the analytical analysis is corroborated by extensive computer simulations, as well as by experiments conducted to determine the of power variation during the startup of a 15 kW electric motor.

An investigation into the extrema of relationship (3) with respect to t demonstrated that all points at which extrema occur for the function p(t) are independent of the values of cos φ -that is of τ, and are determined by the following expression:

$$\omega t_e = \pi/2 + (n-1)\pi \quad (4)$$

where odd values of n correspond to the maxima Pmax, and even values n - to the minima of the total instantaneous power, Pmin.

For circuits with varying current at f = 50 Hz, the first maximum occurs at time t = π/(2ω) = 0.005 s, while the first minimum occurs at t = 3π/(2ω) = 0.015 s. It is quite evident that if a different mains frequency is applied—for example, f = 60 Hz, the temporal parameters will differ.

Figure 1 illustrates the p(t) dependencies, plotted in accordance with expression (1), for cosφ values ranging from 0.2 to 0.7 .

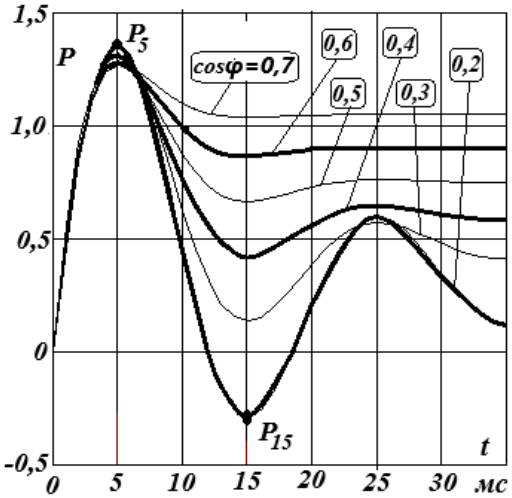

Рис.1 Зависимость p=f(t) при разных значениях cosφ

As is evident from the provided graphs, the maximum values of the total instantaneous power P_5 vary only slightly by 2–4%, as cosφ changes, whereas the minimum values P_{15} differ significantly. As the analysis demonstrated, it is advisable to select as the criterion for determining cosφ not the direct ratio of the extreme power values, but rather the ratio of their difference to their sum, expressed by the coefficient *Kp*:

$$K_p = \frac{P_5 - P_{15}}{P_5 + P_{15}}. \quad (5)$$

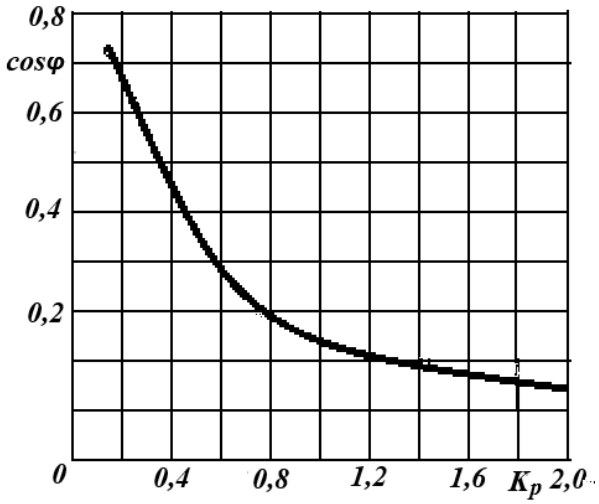

Рис.2 Зависимость cosφ от K_p

Fig. 2 illustrates the relationship between cosφ and the coefficient *Kp*. The range of cosφ values corresponds to the range of cosφ values (0.2–0.7) for test circuits required by regulatory documentation [2].

By utilizing the derived relationship *cosφ=f(Kp)*, the power factor cosφ can be determined based on two power values measured 5 ms and 15 ms after current inception in the test circuit.

The advantage of the proposed method for determining the power factor (cosφ)—which is based on power analysis—lies in the fact that the value of *cosφ* can be easily determined using just two "reference" points, P_5 and P_{15}, from the *p(t)* curve. Specifically, it is necessary to record the instantaneous power values P_5 and P_{15} at 5 ms and 15 ms after the current onset; subsequently, the value of *Kp* is calculated using Formula (5), and the value of *cosφ* is then determined based on the data presented in the graph in Fig. 2. Notably, this approach eliminates the need to employ an operator to perform manual graphical constructions—a requirement inherent to the implementation of the classical method.

2.2Features of the nature of changes in the force function over time

In general, the force function is defined by the following expression:

$$F_s(t) = [i_a(t)]^2 + [i_b(t)]^2 + [i_c(t)]^2 \quad (6)$$

where $i_a(t)$, $i_b(t)$ and $i_c(t)$ are the dependencies of the change in time of phase currents.

After substituting the known expressions of the time change of phase currents, the expression for the force function takes the following form:

$$F_s(t) = 3I_f^2(1 - 2e^{-t/\tau}\cos\omega t + e^{-2t/\tau}) \quad (7),$$

where τ is the electromagnetic time constant, I_f - is the effective value of the phase

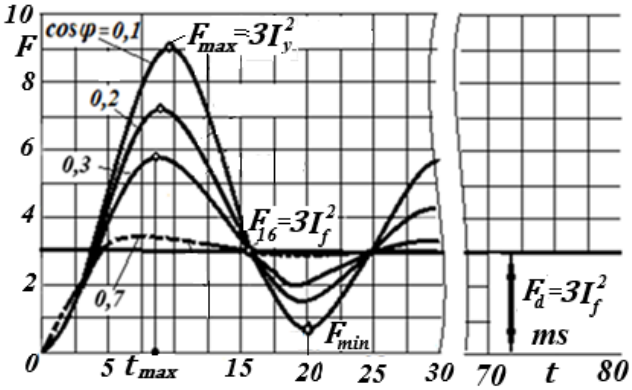

Fig.3 Graphs of the force function at different cosφ values

The main feature of the force function is the independence of its character from the time of the occurrence of the disturbance current. Therefore, the character of the force function $F_s(t)$ depends only on the time constant τ or the power factor $\cos\varphi$. Experimental verification of the nature of the force

function was carried out [6] in circuits with short-circuit currents of the order of 45 kA. Fig.3 shows graphs of the force function at different values $\cos\varphi$.

Let us consider other features of the nature of the force function . If we analyze the expression (6) for the force function $F_s(t)$ by the extremum, then as a result we get the following expression for the pronounced value dF_s/dt:

$$(\cos\omega t_{max}\text{-}\varphi)\text{-}\cos\varphi e^{-\frac{t_{max}}{T}}=0 \quad (8)$$

where t_{max} - is the time for the force function to reach its maximum value F_{max}..

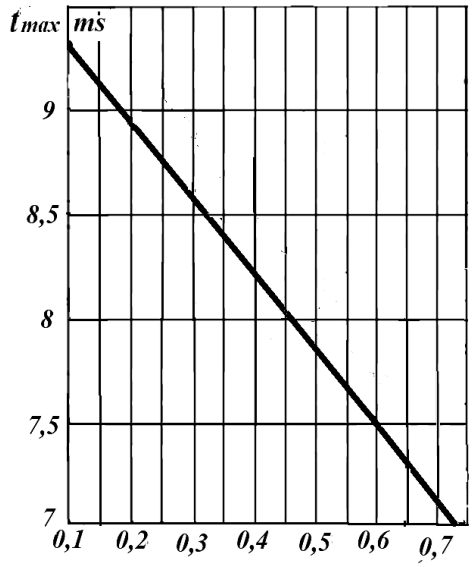

Fig.4 Dependence of time t_{max} on value $\cos\varphi$

A similar expression is obtained for the derivative of the phase current dt in which the shock current occurred I_y due to the fact that the circuit disturbances occurred at the time of the passage of the EMF of this phase through zero. From the equality of expressions for species, it follows that the moment of time when the function $F_s(t)$ reaches its maximum value F_{max} at the same time at which the shock current I_y would arise in one of the phases. Fig.4 shows the dependence of time t_{max} on the value $\cos\varphi$ - $t_{max} = f(cos\varphi)$, obtained by the numerical solution of equation (8).

Let us continue the analysis of the nature of the force function. If we consider that the impact coefficient of the chain K_y is expressed by the following equation $K_y = I_y / I_f$, then the expression (7) for $F_s(t)$ will be as follows:

$$F_s(t) = 3I_y^2 \frac{1-2e^{-t/\tau}\cos\omega t+e^{-2t/\tau}}{K_y^2} \quad (9)$$

For the case where the instantaneous value of the force function reaches its maximum value, the expression F_{max} will be as follows:

$$F_{max} = 3I_y^2 \frac{1-2e^{-t_{max}/\tau}\cos\omega t_{max}+e^{-2t_{max}/\tau}}{K_y^2} \quad (10)$$

Let's transform the denominator in the expression (10). Let us take into account that the times of reaching the values F_{max} and I_y are the same and equal to t_{max}. Let us also take into account that the expressions for the derivatives of the force function and the phase current with the shock current are the same. After a series of substitutions and transformations, we get the following expression of the denominator dF/dt :

$$1 - 2e^{-t_{max}/\tau}\cos\omega t_{max} + e^{-2t_{max}/\tau} = K_y^2 \quad (11)$$

It follows that expression (10) for the reference point of the force function F_{max} will have the following form:

$$F_{max} = 3I_y^2 \quad (12)$$

The magnitude of the shock current I_y is given by the following expression:

$$I_y = \sqrt{F_{max}/3} \quad (13)$$

Let us continue the analysis of the features of the nature of the force function. As can be seen from Fig.3, the value of the function $F_s(t)$ at the moment of time 16 ms after the occurrence of the disturbance current (the value F_{16}) with a small error is equal to the value proportional to the square of the value of the steady state value of the phase current I_f^2.

$$F_{16} \sim 3I_f^2 \quad (14)$$

Hence the following expression for determining the value of the effective value of the phase current I_f :

$$I_f = \sqrt{F_{16}/3} \quad (15)$$

Using expressions (12) and (14), the impact coefficient K_y of the circuit can be defined as the ratio of the value of the shock current to the I_y value of the effective value of the phase current I_f :

$$K_y = \sqrt{F_{max}}/\sqrt{F_{16}} \quad (16)$$

The advantages of the proposed method for determining the value of the shock current I_y and the effective value of the phase current I_f , based on the analysis of the force function are that by two "reference" points F_{max} and F_{16} it is easy to determine the above values I_y and I_f .

To determine the effective value of the current I_f it is necessary to measure the discrete values of the

phase currents at the time 16 ms after the current originates, square them and add them together. The sum of the squares of the specified phase currents constitutes the second reference point of the force function F_{16}. The effective current value is then calculated using the formula $I_f = \sqrt{F_{16}/3}$.

2.3. *Algorithm for the implementation of an alternative method for determining the parameters of the test circuit by a microprocessor device*

Fig.5 shows the algorithm for the implementation by a microprocessor device of an alternative method for determining the parameters of an electrical circuit for testing on a PCS. The algorithm is represented by 3 modules, which do not physically exist, they combine a number of mathematical operations to calculate a particular parameter of the test circuit

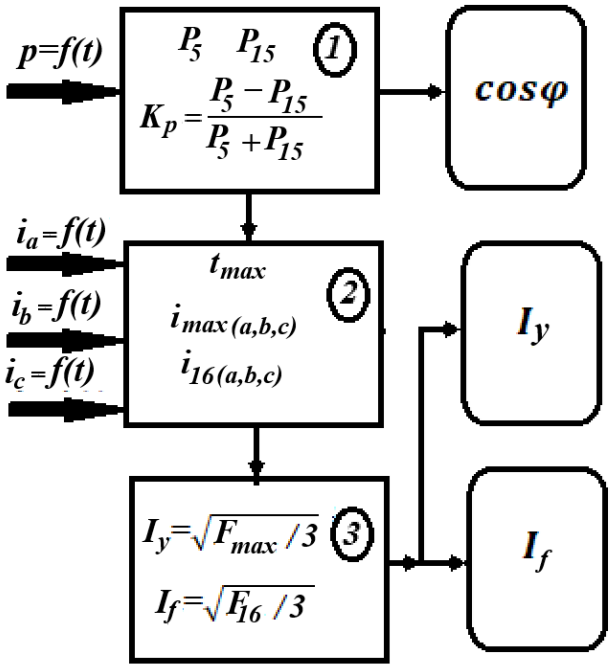

Fig.5 Algorithm for the implementation of an alternative method for determining the parameters of the test circuit

In module 1, instantaneous power values $p = f(t)$ are determined from the incoming information of the total power P_5 and P_{15} at times of time, respectively, *5* ms and 15 P_5 ms after the occurrence of the circuit disturbance. In the same module, the coefficient of P_{15} the ratio of these values is determined from the found values by the expression $K_p = (P_5 - P_{15})/(P_5 + P_{15})$. In the same module, the value of *cosφ* is determined by the dependence of $\cos\varphi = f(K_p)$.

In Module 2 the value t_{max} is determined from the relationship between the time at which the maximum value of the force function occurs t_{max} and the value of cosφ. In the same module, the instantaneous values of the phase currents i_{amax} i_{bmax} and i_{cmax} at the time of the -values t_{max}. In the same module, the instantaneous values of the phase currents at time t= 16 ms after the time of the occurrence of the circuit disturbance are determined - the values i_{a16}, i_{b16} and i_{c16}.

In modulom 3, the values of currents i_{amax}, i_{bmax} and i_{cmax}) are squared and summed up. The sum of these squares of the currents represents the value of the force function F_{max}. In the same module, the magnitude of the shock current I_y is determined by the expression $I_y = \sqrt{F_{max}/3}$. In the same module, the magnitudes of the currents i_{a16}, i_{b16} and i_{c16} are squared and summed up. The sum of the specified squares of the current values is the value of the line of force F_{16} in the same module determine the effective value of the shock current I_f by the expression $I_f = \sqrt{F_{16}/3}$

Summary

A method for automated determination of the parameters of an electrical circuit has been developed to check the maximum switching capacity of electrical devices. This method is an alternative to the method (classical), which is set out in regulatory documents. The classical method is based on the analysis of an oscillogram with the dependence of the change in time of the current in phase. Due to the fact that the nature of the change in the phase current depends on the time of the current occurrence in the electrical circuit, the initial

conditions for processing oscillograms cannot be constant and the most informative. This affects the value of the error in measuring the circuit parameters. The value of the measurement error is also influenced by the level of qualification of the operator when performing the necessary graphic operations in the process of processing oscillograms. The developed alternative method for determining the parameters of the test circuit is based on the analysis of two dependencies of change in time, the nature of which does not depend on the moment of occurrence of current in the circuit, but essentially depends on the value of the power factor of the circuit (cosφ). These dependencies are the time dependence of the total power for the three phases and the force function (the time dependence of the sum of the squares of the instantaneous current values of the three phases). By two reference points for each of these dependencies, it is possible to determine the values of cosφ , the shock current of I_y the circuit, and the effective value of the phase current I_f , using a simple algorithm.

The advantages of the developed alternative method for determining the parameters of the test circuit are the uselessness of the operator for graphic processing of oscillograms, the stability of the results of calculations of parameter values and the automated process of calculating parameter values by a microprocessor device.

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VETERINARY SCIENCES

INVESTIGATION OF THE PROPERTIES OF MYCOBACTERIAL CULTURES ISOLATED FROM BOVINE BLOOD

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Abstract
The species affiliation of mycobacterial cultures isolated from the blood of cattle, as well as reference strains of mycobacteria belonging to Runyon groups II, III, and IV, was determined. The cultural and biochemical properties of the mycobacteria were studied. It was established that the hemocultures of mycobacteria belong to the species *Mycobacterium avium* and exhibit pathogenic properties in rabbits and chickens.

Keywords: mycobacteria, cultural and biochemical properties, laboratory animals, virulence

Introduction

Tuberculosis in farm animals remains a significant issue for livestock production in many countries worldwide [1, 2]. Specific prevention of this disease is not available, as vaccination against tuberculosis is currently not permitted under European Union legislation, due to its interference with diagnostic procedures in eradication programs based on intradermal testing [3].

The main method for ante-mortem diagnosis of tuberculosis is the intradermal tuberculin test using highly specific allergens [4, 5]. However, during routine allergic testing, cases of non-specific reactions in animals to the administration of PPD-tuberculin for mammals have been reported [6, 7].

The nature of these reactions is diverse, but the primary cause is considered to be the sensitization of animals by atypical mycobacteria [8, 9].

Atypical mycobacteria are ubiquitous and exhibit exceptional resistance to adverse environmental factors [10, 11].

Ensuring tuberculosis-free status and effective control of the disease require the development of new diagnostic and preventive methods, which is not possible without analyzing the current epizootic situation [12].

The isolation and identification of mycobacteria as etiological agents of animal tuberculosis and para-allergic reactions to the administration of PPD-tuberculin for mammals remain highly relevant tasks today.

Materials and methods. During the study, 13 mycobacterial cultures were used (6 reference and 7 field isolates (*M. avium*)), including 8 strains of *Mycobacterium avium* and 5 strains of atypical mycobacteria belonging to Runyon groups II (*M. scrofulaceum*), III (*M. intracellulare*), and IV (*M. fortuitum, M. phlei, M. smegmatis*) according to the Runyon classification (1959).

The experimental mycobacterial cultures were cultivated on solid Helberg nutrient medium. Species identification of mycobacteria was performed using biochemical tests (Tween 80 hydrolysis, amidase activity—nicotinamidase, pyrazinamidase, urease—catalase activity, and tellurite reduction) and cultural characteristics (growth rate, ability to grow at 22.0 °C, 42.0 °C and 45.0 °C, and tolerance to 5.0 % NaCl in the medium).

The studies were conducted in accordance with the *Guidelines for the Identification of Mycobacterial Cultures* (Kharkiv, 2015).

Biological studies were conducted in accordance with current regulatory documents using laboratory animals (rabbits, chickens, and guinea pigs). All manipulations were performed under conditions aimed at minimizing stress and suffering of the animals. The study was conducted in accordance with the European Convention for the Protection of Vertebrate Animals used for Experimental and Other Scientific Purposes [13].

Research results. In order to determine or confirm the species identity of mycobacterial cultures isolated from cattle blood, as well as reference cultures, their cultural (growth rate, colony morphology, photochromogenicity, and growth at 25.0°C, 37.0°C, and 45.0°C) and biochemical properties (tolerance to 5.0% NaCl, accumulation of citrate-ammonium iron, catalase activity, reaction with potassium tellurite, Tween 80, and amides) were studied.

Based on the results of studying the cultural and biochemical properties of mycobacterial cultures (Table 1), it was established that all 7 cultures (Nos. 2–8) isolated from cattle blood (hemocultures), as well as 6 reference (control) cultures (Nos. 1, 9–13), exhibited characteristic cultural and biochemical features typical of the respective mycobacterial species belonging to Runyon groups II, III, and IV.

Table 1.

Study of the Cultural and Biochemical Properties of Mycobacteria Isolated from the Blood of Cattle

No.	Mycobacterial cultures	Primary growth, days	Growth at temperature			Pigment production	Iron accumulation	Tolerance to 5% NaCl	Catalase activity	Reaction with potassium tellurite	Tween 80 hydrolysis	Amidase activity	
			25.0 °C	37.0 °C	45.0 °C							Nicotinamide	Pyrazinamide
1	*M. avium № 61*	17.0±2.4	+	+	+	*N*	+	+	+	+	+	+	+
2	*M. avium 8/07*	4.0±0.6	+	+	+	*N*	–	–	–	+	+	+	+
3	*M. avium 9/07*	3.0±0.5	+	+	+	*N*	+	+	+	+	+	+	+
4	*M. avium 15/07*	18.0±2.9	+	+	+	*C*	–	–	–	+	+	+	+
5	*M. avium 22/07*	4.0±0.3	+	+	+	*N*	+	+	+	+	+	+	+
6	*M. avium 36/07*	5.0±0.8	+	+	+	*N*	+	–	–	+	+	+	+
7	*M. avium 63/07*	20.0±3.1	+	+	+	*N*	+	–	–	+	+	+	+
8	*M. avium 64/07*	19.0±3.3	+	+	+	*C*	–	–	+	+	+	+	+
9	*M. scrofulaceum*	15.0±2.7	+	+	+	*N*	+	+	–	+	+	+	+
10	*M. intracellu-larae*	15.0±2.3	+	+	+	*C*	+	–	–	–	+	+	+
11	*M. smegmatis*	3.0±0.7	+	+	+	*N*	+	+	+	+	+	+	+
12	*M. fortuitum*	7.0±1.6	+	+	+	*N*	–	+	–	+	+	+	+
13	*M. phlei*	8.0±±1,2	+	+	+	*N*	–	+	–	+	+	+	+

Notes: "+" – positive reaction; "–" – negative reaction; N – no pigment; C – pigment present

To study the pathogenic and virulent properties of the experimental hemocultures of mycobacteria, a biological assay was performed on susceptible laboratory animals. A total of 26 guinea pigs, 10 rabbits, and 10 chickens were selected for the study. The selected animals were clinically healthy and aged 3–4 months.

Prior to the experiment, the animals were subjected to an allergic test in accordance with the current Guidelines for the Use of Tuberculins for the Allergic Diagnosis of Tuberculosis in Mammals and Birds (1994).

The reactions in guinea pigs and rabbits were recorded at 24 and 48 hours, respectively, and in chickens at 30–36 hours. In all selected animals, allergic reactions to PPD-tuberculin for mammals and birds, as well as to atypical mycobacteria antigen (AAM), were negative.

Subsequently, the animals were inoculated with a suspension of mycobacterial cultures at a concentration of 1.0 mg of bacterial mass per 1.0 cm³ of sterile isotonic solution, administered at a dose of 1.0 cm³ per animal. Rabbits and chickens were inoculated with suspensions of *M. avium* cultures only, while guinea pigs received a mixture of all experimental hemocultures.

The laboratory animals were observed for 90 days. Allergic testing was performed periodically, once every 30 days, and in the event of animal death, pathological material was collected for bacteriological examination for tuberculosis.

It was established that all experimental mycobacterial cultures caused enlargement of regional lymph nodes in guinea pigs. During the study period, transient positive reactions to allergen administration were observed. At the site of inoculation of the mycobacterial suspension, guinea pigs exhibited hyperemia and swelling up to 4 mm in diameter, while chickens showed thickening and hyperemia of the wattles.

The study of the virulent properties of *M. avium* in rabbits and chickens demonstrated its virulent activity. The results of biochemical studies for species identification of the cultures were also confirmed.

The experimental mycobacterial cultures exhibited pronounced virulent effects in laboratory animals. In rabbits, signs of cachexia gradually developed following infection. By day 23 post-inoculation, six rabbits infected with *M. avium* cultures (reference strain, No. 63/07, and No. 64/07) had died.

Post-mortem examination of the dead rabbits revealed hepatosplenomegaly, generalized emaciation, and enlargement of lymph nodes, indicating a septic form of the disease (Yersin type). Rabbits infected with culture No. 15/07 died on day 33 of the experiment. Pathological examination showed a similar pattern (sepsis) as in the previous animals, along with joint swelling and the presence of seropurulent fluid in the synovial sacs. During necropsy, pathological material from all rabbits was collected for bacteriological examination. A rabbit infected with *M. intracellulare* died on day 60 post-inoculation. However, no characteristic tuberculous lesions were observed at necropsy, and tissue samples (liver, spleen, lungs) were collected for further bacteriological analysis.

Mortality in chickens was observed начиная from day 46 of the experiment. Chickens infected with *M. avium* (reference strain) and culture No. 64/07 died on day 46, exhibiting characteristic signs of emaciation, weight loss, feather loss, and swollen, hyperemic wattles. At necropsy, enlargement of the liver and spleen

was noted, with characteristic white-gray nodules on the surface and within the parenchyma of these organs. The spleen was enlarged, edematous, and had a purple-red coloration. Chickens that died on day 48 of the experiment showed similar clinical signs and pathological changes at necropsy.

Guinea pigs infected with the experimental cultures did not die during the course of the experiment. After 90 days, the guinea pigs were euthanized, and biological material was collected for bacteriological examination. At necropsy, no pathological changes characteristic of tuberculosis were observed, except for enlargement of regional lymph nodes. During bacteriological examination of pathological material collected from all experimental laboratory animals, the original mycobacterial cultures were re-isolated. Thus, the conducted studies made it possible to determine the species identity of the isolated mycobacterial hemocultures and to investigate their cultural, morphological, sensitizing, pathogenic, and virulent properties.

Conclusion

1. Mycobacterial cultures isolated from the blood of cattle that showed a positive reaction to the intradermal administration of PPD-tuberculin for mammals belong to the *Mycobacterium avium–intracellulare* complex. Based on cultural and biochemical characteristics, seven of the isolated mycobacterial cultures were identified as *Mycobacterium avium*.

2. Mycobacteria of the *Mycobacterium avium–intracellulare* complex are pathogenic for rabbits and chickens.

3. Atypical mycobacteria of Runyon groups II, III, and IV induce sensitization to PPD-tuberculin for mammals in guinea pigs and are non-pathogenic for this species of laboratory animals.

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IMPACT OF GLOBAL CLIMATE CHANGE ON LIVESTOCK (In the Conditions of the Nakhchivan Autonomous Republic)

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AUSWIRKUNGEN DES GLOBALEN KLIMAWANDELS AUF DIE VIEHHALTUNG (unter den Bedingungen der Autonomen Republik Nachitschewan)

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Abstract

Global climate change is one of the main factors seriously affecting the sustainable development of the livestock sector. The continental and arid climatic conditions of the Nakhchivan Autonomous Republic further strengthen these effects. In recent years, rising temperatures, decreasing precipitation, and prolonged drought periods have led to a decrease in the biomass of pasture plants, a weakening of the feed base, and a decrease in animal productivity. Heat stress reduces milk yield in large horned animals, weakens reproductive performance, and increases susceptibility to diseases. Studies show that a decrease in pasture productivity increases feed costs for farms and limits economic profitability. The article analyzes the effects of climate change on animal health, productivity and the economy of the region on a scientific basis, and also puts forward recommendations on adaptation measures and sustainable livestock models.

The climatic and soil conditions of the Nakhchivan Autonomous Republic are considered favorable for the cultivation of green fodder plants. Alfalfa, corn, barley-corn mixtures and other plants that yield green mass are cultivated in various zones, and these products are widely used in livestock farms. In local conditions, expanding the green fodder base reduces the need for feed imports and increases the profitability of farms.

Zusammenfassung

Der globale Klimawandel ist einer der Hauptfaktoren, der die nachhaltige Entwicklung des Viehsektors erheblich beeinträchtigt. Die kontinentalen und ariden Klimabedingungen der Autonomen Republik Nachitschewan verstärken diese Auswirkungen zusätzlich. In den letzten Jahren haben steigende Temperaturen, sinkende Niederschläge und anhaltende Dürreperioden zu einem Rückgang der Weidepflanzenbiomasse, einer Schwächung der Futtergrundlage und einer geringeren Tierproduktivität geführt. Hitzestress reduziert die Milchleistung bei Großtieren mit Hörnern, beeinträchtigt die Fortpflanzungsleistung und erhöht die Krankheitsanfälligkeit. Studien zeigen, dass eine sinkende Weideproduktivität die Futterkosten für die Betriebe erhöht und die Wirtschaftlichkeit mindert. Der Artikel analysiert die Auswirkungen des Klimawandels auf Tiergesundheit, Produktivität und die Wirtschaft der Region auf wissenschaftlicher Grundlage und gibt Empfehlungen zu Anpassungsmaßnahmen und nachhaltigen Viehhaltungsmodellen.

Die klimatischen und Bodenbedingungen der Autonomen Republik Nachitschewan gelten als günstig für den Anbau von Grünfutterpflanzen. In verschiedenen Gebieten werden Luzerne, Mais, Gersten-Mais-Mischungen und andere ertragreiche Grünfutterpflanzen angebaut, deren Produkte in der Viehhaltung weit verbreitet sind. Der Ausbau der Grünfutterbasis reduziert unter den lokalen Bedingungen den Bedarf an Futtermittelimporten und steigert die Rentabilität der Betriebe.

Keywords: climate change, livestock, Nakhchivan, drought, productivity, adaptation.
Schlüsselwörter: Klimawandel, Viehhaltung, Nachitschewan, Dürre, Produktivität, Anpassung.

Einleitung

Das Auftreten globaler, planetarischer Umweltprobleme ist ein Problem, das im 20. Jahrhundert Einzug in die Menschheit gehalten hat. Der Mensch, der sich in einem beständig negativen Verhältnis zur Umwelt befindet, gräbt, zerstört,

verbrennt und vernichtet die Ressourcen des Planeten, verändert die Struktur von Wasser und Luft, verringert die Bodenfruchtbarkeit und verarmt sie – dieser unkontrollierte Prozess wird als menschliche Entwicklung bezeichnet. Nie zuvor gab es eine so große Bedrohung für die Umwelt angesichts der Versorgung der rasant wachsenden Weltbevölkerung mit natürlichen Ressourcen. Nie zuvor hatte der Mensch einen so starken Einfluss auf die Umwelt. Anders als anthropogene Umweltkatastrophen nimmt der gegenwärtige Einfluss des Menschen auf die Biota (die Gesamtheit aller Lebewesen der Biosphäre) einen globalen Charakter an und beschränkt sich nicht auf ein oder mehrere Ökosysteme, sondern umfasst den gesamten Planeten. Die Auswirkungen der wissenschaftlichen und technologischen Revolution führen zu tiefgreifenden Veränderungen in der Biosphäre, hinterlassen tiefe Spuren und verursachen das Auftreten ökologischer Phänomene. Aus all diesen Gründen sind Umweltprobleme zu den wichtigsten globalen Problemen der modernen Welt geworden und haben politische Bedeutung erlangt [3, S.152].

Das Problem der Nahrungsmittelproduktion ist eng mit der Dynamik der Weltbevölkerung verknüpft und hat sowohl globale als auch lokale Dimensionen.

Auch Aserbaidschan ist von den Auswirkungen des globalen Klimawandels betroffen. In den letzten 100 Jahren sind die durchschnittlichen Jahrestemperaturen in Aserbaidschan um 0,4 bis 1,3 °C gestiegen. Der Klimawandel gefährdet die Ernährungssicherheit und den Zugang zu Wasser auf regionaler und globaler Ebene, führt zu Hunger, Armut und anderen schwerwiegenden sozioökonomischen Folgen, verstärkt Migration und begünstigt Infektions- und chronische Krankheiten. Nicht umsonst bezeichnet die Weltgesundheitsorganisation (WHO) den Klimawandel als die größte Bedrohung für die globale Gesundheit im 21. Jahrhundert. Experten zufolge werden selbst bei erfolgreichen Bemühungen zur Eindämmung der globalen Erwärmung einige negative Auswirkungen, wie der Anstieg des Meeresspiegels, der Ozeantemperaturen und der Versauerung der Ozeane, noch Jahrhunderte anhalten [4, S. 243].

In der heutigen Zeit hat die Volkswirtschaft unserer unabhängigen Republik die Übergangsphase hinter sich gelassen und ist in eine neue, verantwortungsvolle Phase eingetreten – die Phase der Umsetzung konkreter Maßnahmen zur Erneuerung und Stärkung. Infolge umfassender Wirtschaftsreformen haben sich neue Formen der Nutzung aller bestehenden Nutztierarten herausgebildet. Dadurch haben sich auch die Einstellung zur Tierhaltung, deren Management und die Art der Tierhaltung grundlegend verändert. Um die Krise unserer Gesamtwirtschaft zu überwinden, wurde in unserem Land ein aserbaidschanisches Modell der Agrarreformen entwickelt, zu dem auch die Reform der Einstellung zur Tierhaltung als Bestandteil gehört. Um den Entwicklungsstand aller in der Republik Aserbaidschan gehaltenen Tierarten weiter zu verbessern, wurden im Land gezielte und geplante Spezialisierungen und Standortanpassungen vorgenommen. So ist in großen Industriezentren, Hauptstädten und Großstädten mit hoher Bevölkerungsdichte die Milchviehhaltung in Regionen, die Milch- und Fleischviehhaltung in relativ abgelegenen Regionen und die Fleischviehhaltung in noch abgelegeneren Regionen mit ausgedehnten Weideflächen vorgesehen, sowie die Ansiedlung hochproduktiver Zuchttiere mit der genannten Produktivitätsorientierung in diesen Regionen [2, S. 10].

Das Hauptziel der staatlichen Tierhaltungspolitik ist die vollständige Deckung des Bedarfs der Bevölkerung an tierischen Produkten [6, S. 295].

Infolge des durch den Klimawandel bedingten Rückgangs der Niederschläge kann es während der Aussaat- und Weideperioden zu einem akuten Wassermangel kommen. Laut offizieller Statistik werden in Aserbaidschan über 80 Prozent der landwirtschaftlichen Erzeugnisse auf bewässerten Flächen produziert. Daher kann die durch den Klimawandel bedingte Verknappung der Wasserressourcen die Landwirtschaft erheblich belasten. Um die Auswirkungen des Klimawandels auf die Landwirtschaft zu minimieren und ihre Anpassung an den Klimawandel zu maximieren, ist es notwendig, die Maßnahmen zur effizienten Bewirtschaftung von Acker- und Weideflächen zu verstärken und den rechtlichen Rahmen zu verbessern.

In den letzten Jahrzehnten hat der globale Klimawandel die Nachhaltigkeit der Landwirtschaft weltweit erheblich beeinträchtigt. Steigende Temperaturen, ungleichmäßige Niederschlagsverteilung, anhaltende Dürreperioden und häufigere Extremwetterereignisse haben zu geringerer Produktivität in der Tierhaltung, vermehrtem Krankheitsbefall und einer Schwächung der Futtergrundlage geführt. Die Autonome Republik Nachitschewan zählt aufgrund ihrer Halbwüsten- und Gebirgslandschaft zu den am stärksten vom Klimawandel betroffenen Gebieten. Daher ist die Frage der Nachhaltigkeit der Tierhaltung in dieser Region von besonderer wissenschaftlicher und praktischer Bedeutung [2, S. 17].

Die Auswirkungen des Klimawandels sind umstritten. Dieser Artikel untersucht die Folgen des Klimawandels für die Nutztierhaltung auf Grundlage der Theorie der globalen Erwärmung. Obwohl die Auswirkungen der globalen Erwärmung nicht überall negativ sind, wird ein entsprechender Anstieg von Dürren erwartet, der die Futter- und Pflanzenproduktion weltweit beeinträchtigen wird. Wärmere Umgebungen beeinträchtigen die Produktivität (Wachstum, Fleisch- und Milchleistung und -qualität, Eierproduktion, Gewicht und Qualität) sowie die Reproduktionsleistung, den Stoffwechsel- und Gesundheitszustand und die Immunantwort [8, S. 14].

Es ist bekannt, dass in der modernen Phase der wirtschaftlichen Entwicklung die Begrenzung von Importen und die damit einhergehende Förderung der lokalen Produktion sowie letztlich die Steigerung des exportorientierten Produktionsvolumens zu den wichtigsten makroökonomischen Zielen zählt. Die geplanten Maßnahmen zielen daher darauf ab, die Produktion landwirtschaftlicher Erzeugnisse zu

steigern, um so die Inlandsnachfrage zu decken und das Exportvolumen zu erhöhen [7, S. 32].

Die Produktivität in der Tierzucht ist, ebenso wie Tierernährung, Haltungsbedingungen und genetisches Potenzial, stark von klimatischen Faktoren abhängig.

Ziel dieser Arbeit ist es, die negativen und positiven Auswirkungen des Klimawandels auf die Tierzucht wissenschaftlich fundiert darzustellen und die Rolle neuer Technologien und innovativer Ansätze bei der Minderung dieser Auswirkungen zu erläutern [1, S. 97].

Steigende Temperaturen führen zu vermehrtem Hitzestress bei Tieren. Dieser äußert sich in Form von verringerter Milchleistung, reduzierter Futteraufnahme, verminderter Fortpflanzungsfähigkeit und einem geschwächten Immunsystem. Insbesondere bei großen Horntieren sinkt die Milchleistung um 3–5 % pro Grad Celsius Temperaturanstieg. Zudem weitet sich das Verbreitungsgebiet von Parasiten- und Bakterienkrankheiten aus, und die Seuchenlage verschärft sich [9, S. 26].

Das Klima in Nachitschewan ist kontinental und arid. Im Sommer steigen die Lufttemperaturen auf 35–40 °C, und die jährliche Niederschlagsmenge liegt zwischen 200 und 300 mm. Die Viehzucht, einer der wichtigsten Erwerbszweige der Bevölkerung, ist direkt von den Wasserressourcen und dem Schutz der Weidevegetation abhängig. Infolge des Klimawandels wurden in den letzten Jahren ein Rückgang der Flusswasserführung, Bodenversalzung und eine sinkende Produktivität der Weidepflanzen beobachtet [5, S. 93].

Die Weideflächen in Nachitschewan liegen hauptsächlich in den Vorgebirgen und Halbwüsten. Sinkende Niederschläge und steigende Temperaturen verringern die Biomasse der Weidepflanzen und mindern die Futterqualität. Die Schwächung der Futtergrundlage führt zu höheren Kosten und geringerer Produktivität in der Viehhaltung. Die saisonal ungleichmäßige Verteilung der Futterressourcen in der Region birgt zusätzliche Risiken. [5, S. 219].

Um die Tiere dauerhaft mit Grünfutter zu versorgen, sollten die Pflanzenarten den klimatischen Bedingungen des Gebiets angepasst werden. Landwirte sollten dies besonders beachten. Die Boden- und Klimabedingungen unserer Heimat bieten hervorragende Voraussetzungen für den Anbau aller landwirtschaftlichen Nutzpflanzen und hohe Erträge. Bei effektiver Nutzung kann den Tieren hochwertiges Grünfutter zur Verfügung gestellt werden. [10, S. 49].

Die Viehzucht spielt eine wichtige Rolle im Agrarsektor von Nachitschewan. Sinkende Produktivität, steigende Kosten für Medikamente und Präventionsmaßnahmen sowie Schwierigkeiten bei der Futterversorgung mindern die Rentabilität der Betriebe. Schwankungen bei den Marktpreisen für Milch, Fleisch und Wolle beeinträchtigen die Stabilität des Agrarmarktes. [5, S. 268].

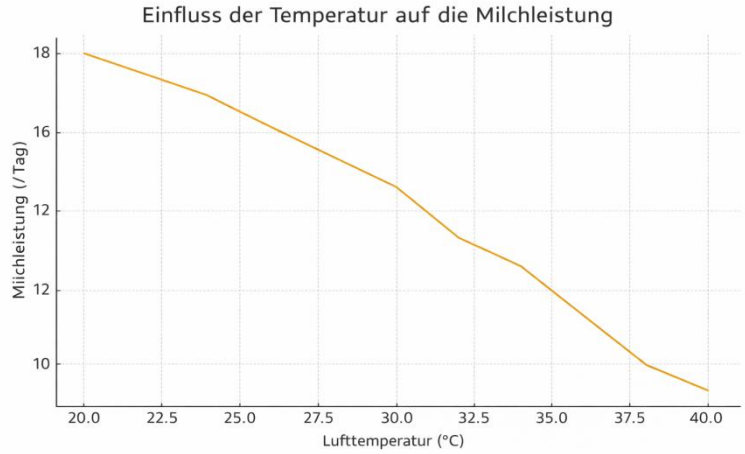

Diagramm 1. Einfluss der Temperatur auf die Milchleistung.

Die Forschung basiert auf der Analyse meteorologischer Indikatoren, dem Vergleich von Tierproduktivitätsindikatoren in landwirtschaftlichen Betrieben und Methoden zur Überwachung der Ausbreitungsdynamik von Tierseuchen. Die Daten wurden anhand lokaler Statistikämter, meteorologischer Beobachtungen und Betriebsdaten erhoben.

Der globale Klimawandel hat gravierende Auswirkungen auf die Nachhaltigkeit der Tierhaltung in der Autonomen Republik Nachitschewan. Erwärmung und Verknappung der Wasserressourcen führen zu einer Schwächung der Futtergrundlage, einem Anstieg von Krankheiten und einem Rückgang der Produktivität. Um diese Auswirkungen zu reduzieren:

Tabelle 1.

Ökonomische Nachhaltigkeit von landwirtschaftlichen Betrieben

Strategie	Hauptveranstaltungen
Technologische Anpassung	Implementierung von Belüftungs-, Kühlsystemen, automatischer Bewässerung und Beschattungseinrichtungen
Genetische Anpassung	Selektion und Vermehrung lokaler, hitzetoleranter Rassen mit staatlicher Unterstützung
Optimierung der Futtermittelproduktion	Ausbau wassersparender Technologien für Futterpflanzen, Silage und Heutrocknung
Stärkung der Veterinärkontrolle	Verbesserung der Systeme zur Überwachung von Tierseuchen und Optimierung der Impfprogramme

Diese Maßnahmen erhöhen die Stressresistenz der Tiere, stabilisieren die Produktivität und sichern die wirtschaftliche Nachhaltigkeit der Betriebe.

Fazit

Der globale Klimawandel beeinflusst direkt und indirekt alle Bereiche der Tierproduktion – Tiergesundheit, Futtermittelproduktion, wirtschaftliche Indikatoren und die Struktur der Sozialfürsorge. Daher sollten sowohl auf nationaler als auch auf regionaler Ebene umfassende Anpassungsmaßnahmen umgesetzt und nachhaltige Tierhaltungsmodelle entwickelt werden. Die Anwendung neuer Managementstrategien, die lokale Klimabedingungen, das ökologische Gleichgewicht und die Biodiversität berücksichtigen, wird eine wichtige Rolle für die zukünftige Ernährungssicherheit spielen.

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